Studies in the Post-Glacial History of British Vegetation. XI. Late-Glacial Deposits in Cornwall

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STUDIES IN THE POST-GLACIAL HISTORY OF BRITISH VEGETATION
XI. LATE-GLACIAL DEPOSITS IN CORNWALL

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[Plates 24 and 25]

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In a series of profiles at the china-clay pits at Hawks Tor, Bodmin Moor, Cornwall, a stratigraphy was found resembling that typical of the late-Glacial Allerød oscillation. Gravelly-soil layers showing solifluction phenomena overlie the organic muds and peats of a small channel, and these gravels are in turn thickly overlaid with peat. Pollen-analyses from this site, reinforced by series from neighbouring sites, make it clear that the peat above the solifluction gravel must be referred to the early post-Glacial period.

Identification of fruits, seeds, etc., from the organic layers near the overlying and underlying gravels shows the presence of many plants now restricted to more northerly parts of the country, such as *Betula nana*, *Salix herbacea* and *Thalictrum alpinum*. Pollen-analyses show assemblages of genera and species of herbaceous plants recognized as typical of the open 'tundra' or 'park-tundra' conditions found elsewhere in Europe in this period; these include the genera *Helianthemum*, *Armeria*, *Artemisia*, *Thalictrum*, *Plantago* and *Polemonium*.

Evidence that the muds and peats beneath the upper gravel layer were formed in a period of amelioration is found in the formation of the organic layers themselves, in the diatom flora, which has a preponderantly cool-temperate character, and in the presence of a few mosses and phanerogams of more southerly distribution type. The evidence does not make it apparent whether closed woodland characterized this period.

There seems no doubt that these deposits represent the late-Glacial period, and the authors make a tentative zonal correlation between them and zoned deposits of similar age elsewhere in Britain and other parts of north-west Europe, extending through the Allerød oscillation.

The lists of microscopic and macroscopic plant identifications from the recognized zones provide evidence of the presence of a large number of plant species at a time and place of great interest and importance in the history of the British flora.

1. Introduction

(a) *The late-Glacial period and the Allerød oscillation*

A very great increase in our knowledge of the vegetation, climate, archaeology and correlated phenomena of the prehistoric post-Glacial period has resulted from the application of pollen-analytic methods to the investigation of peat-bogs, lake and beach deposits throughout most countries of Europe. As the outlines of this picture have gained coherence it has become increasingly apparent that we remain very ignorant of the preceding period, the late-Glacial, which (at any rate in regions near the ice-margin of the last glaciation) intervened between the full Glacial and the post-Glacial period. During the last 15 or 20 years, however, botanists and geologists, particularly the Scandinavians, have published the results of a series of valuable investigations upon the detailed sequence of events of this period (see Godwin 1947). The most substantial result of this work depends upon the recognition of a late-Glacial climatic oscillation, the so-called Allerød oscillation, which was a phase of temporary warmth and succeeding coldness interrupting the general uniformity of climatic amelioration at the end of the Ice Age. At the type site at the tile works at Allerød in Zealand, Hartz & Milthers (1901) described a stratigraphic sequence which has come to be recognized as very highly characteristic. Within a small lake basin in the boulder-clay of the terminal moraine, during the warm phase of the Allerød oscillation, there were deposited organic lake muds with remains of phanerogamic plants indicative of relatively mild climatic conditions. These were, however, sealed in by stony sands and clays of a character only to be interpreted as due to the solifluction movement of surface material from surrounding slopes under the influence of alternate freezing and thawing. The recognition of ‘arctic’ plants, such as *Dryas octopetala* and *Betula nana*, from the solifluction earth confirmed the inference of climatic recession after the mild period in which the organic lake-muds were formed and in which tree birches flourished.

The prevalence of remains of *Dryas octopetala* in a sequence of this kind had already been appreciated in central Europe, and the terms ‘upper *Dryas* clays’ and ‘lower *Dryas* clays’ had come into use for the beds respectively above and below the deposits of the passing mild period. Investigations, extensive and intensive, have recently multiplied our knowledge of the period, especially in Denmark, southern Sweden, Norway and northern Germany. Pollen-analysis has been extended backwards from early post-Glacial to late-Glacial deposits, and the zoning of both has been unified. Thus Jessen’s zone I corresponds with deposition of the lower *Dryas* clays, zone II with the mild Allerød period, and zone III with the upper *Dryas* clays. J. Iversen’s extension of detailed analysis to pollen of herbaceous plants has permitted him and his followers to go far towards recognizing the vegetation types present in Denmark throughout these zones, and he has given the name 'park tundra' to the open grass- and sedge-dominated vegetation of zones I and III, when only scattered trees dotted the landscape. During zone II more or less closed birch woods or birch-pine woods developed and the park tundra species were correspondingly repressed. Long lists of mammals indicate the nature of the fauna, and the luxuriant herbaceous vegetation of the park tundra is clearly associated with the sustenance of great numbers of giant mammals such as reindeer (*Cervus tarandus*), bison (*Bison bonasus*), horse (*Equus caballus*) and giant Irish deer (*Cervus megaceros*). A few, but very important, investigations have linked these late-Glacial phenomena with substantial archaeological cultures of types which effect the junction between late Palaeolithic and Mesolithic.

By reference to the distribution of Allerød sites it has become apparent that the great Salpausselka end-moraine stage of Glacial retreat in all probability corresponds with the climatic worsening of zone III. This permits a dating from de Geer's already worked out varve analyses, of 8500 B.C., for the stage which Jessen has proposed should separate the late-Glacial from the post-Glacial, namely, the time when tree growth first became dominant over the open tundra vegetation in southern Scandinavia.

In Great Britain the greater part of our knowledge of the late-Glacial period concerns Ireland, and derives from the very extensive work done in that country by Professor Jessen, his assistants and Dr Mitchell of Trinity College, Dublin. The typical Allerød sequence was demonstrated beyond question at Ballybetagh when Farrington showed that zone III was coincident with the local Wicklow Mountain glaciation. Here, as at other sites, the calcareous marls of zone II have been associated with reindeer and giant Irish deer, whilst typical 'arctic' plants have been identified. From the large number of sites described by Jessen it is possible to recognize that the course of development of late-Glacial conditions was similar in Ireland and in southern Scandinavia, although the resemblance is affected by the more oceanic character of the Irish climate.

In Great Britain we naturally seek sites which will serve to link the evidence for Eire with that for Denmark and its neighbouring countries, but little has as yet been accomplished. Dr W. Tutin has made a good case for recognizing the Allerød sequence in the alternation of banded lake-clays and organic muds in the basin of Windermere (Pennington 1947), and Mitchell has reported initial findings at a site, Flitwick Moor, Berwickshire, which in stratigraphy and plant content strongly resembles the Irish late-Glacial sequence (Mitchell 1948). Other sites have been mentioned more speculatively (Godwin 1947).

It is against this background situation that we have to regard the results of the Hawks Tor investigations.

(*b*) *Initial observations on topography and stratigraphy*

The elevated area known as Bodmin Moor has been formed by the intrusion of a granitic mass through the surrounding Devonian slates. Its high tors of outcropping granite often reach above 1000 ft.

The mass is cut into by two shelves or plateaux at about 750 and 1000 ft. O.D. respectively. Near the upper margins of these two shelves are wide gently sloping depressions, now covered with peat. It will be seen from the maps that Crowdy Marsh lies on the 1000 ft. platform, and Stannon Marsh on the 750 ft. It has been shown that these flats or hollows are associated with kaolinization of the granite floor, and that the valleys have formed by linking together a chain of such depressions. Excavations in search of china-clay have demonstrated that the marshes coincide exactly with the kaolinized areas, and end where such areas abut upon the steeply rising margin of unaltered rock. Writing of the kaolinization of the granite the authors of the Geological Survey Memoir (Reid, Barrow & Dewey 1910) describe it thus: 'The great age of the alteration is perhaps best shown by the dominant influence of the presence of these kaolinised masses in the development of the main features of the scenery. The granite area may be described as a mass of rising ground intersected by a considerable number of valleys, the peculiarity of which is that they are composed of alternations of comparatively narrow and broad portions. In the latter the stream has always a very slow fall, the ground is almost waterlogged and, where undisturbed, is covered by a thick sheet of peat; in fact it is a typical Cornish marsh. Wherever the floor or "shelf" of these marshes has been tested the granite has invariably been found to be more or less kaolinised; so soon as this kaolinisation ceases the valley at once narrows, or, as the stream tinners put it, "the sides of the hills come together".'

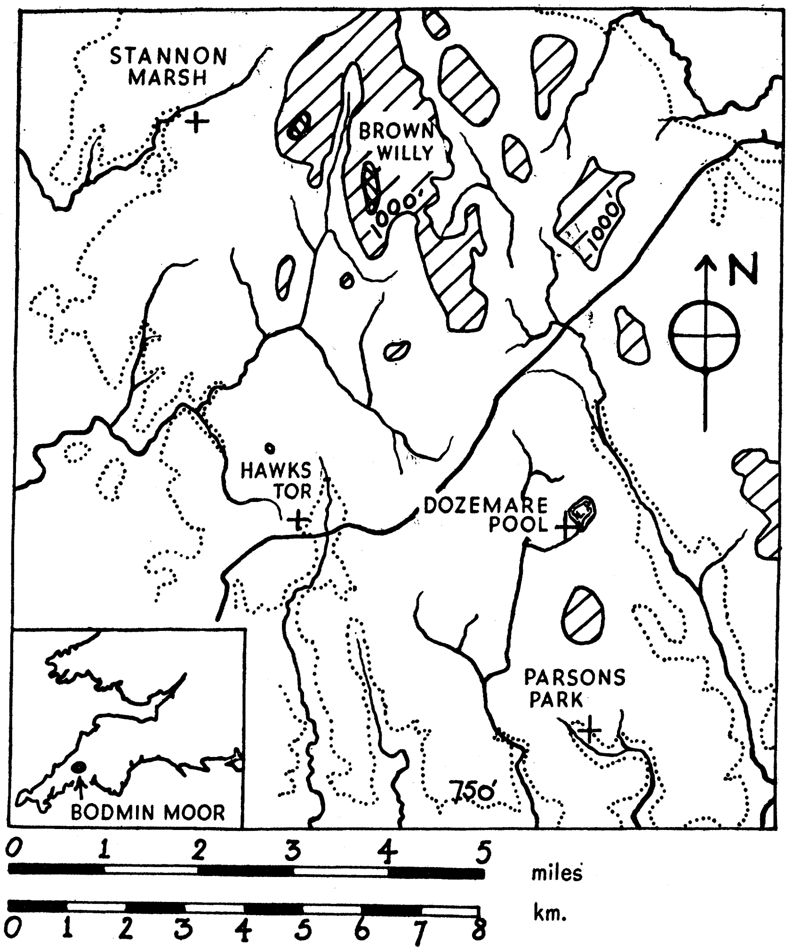

FIGURE 1. Sketch-map showing positions of sites referred to in the text.

Hawks Tor, which rises to 1006 ft., is about 1½ miles north of the village of Temple; the main road from Bodmin to Launceston passes between it and this village. Slightly to the east, about 500 yards north of this road, near Temple Bridge, are the Hawks Tor China-

Clay Works lying in a broad flat on the upper reaches of the slow-falling valley of the Warleggan river, which, higher up, runs between Hawks Tor on the west and Brockabarrow Common rising to 1009 ft. on the east. The china-clay works lie on the 750 ft. contour, so that this flat appears to be part of the 750 ft. platform mentioned above. A typical moorland marsh lies in this hollow, dominated throughout by *Molinia caerulea* save in the central stream complex.

This kaolin pit was first visited in the autumn of 1935, and immediately attracted notice from the fact that the excavations had exposed a very long face of deep peat above the kaolinized granite. In places the peat was as much as 10 ft. (3·05 m.) thick, and then exhibited the stratigraphy shown in the field-notes reproduced below.

North face of kaolin pit, Hawks Tor, Bodmin Moor, 1935

	depth (ft.)
Molinia-dominated vegetation—surface	0
brown, fibrous *Molinia* peat, *Calluna* locally	0 to 2·5
black, fibrous *Molinia*, *Eriophorum vaginatum* peat, with some charcoal at 3·5 ft.	2·5 to 5·5
wood-layer with abundant *Betula*	at 5·5
black, amorphous peat	5·5 to 7·0
coarse granitic gravel, silty at base	7·0 to 8·5
light brown peat with abundant twigs (? *Salix*) in upper layers, gyttja with abundant *Carex* and *Menyanthes* fruits below	8·5 to 10·0
coarse granitic gravel	

The profile at such a place might be described in general terms as consisting of an upper layer of fresh *Molinia* peat overlying a highly humified black *Molinia-Eriophorum* peat with a wood and bark layer at its base. Below this was thin humified black peat resting upon coarse white granitic gravel containing irregular seams of peaty material. Beneath this gravel was a laminated organic lake-mud (nekron-mud) resting upon the kaolinized gravel of the pit. It was from the first difficult to imagine how any stream in this short and gentle valley could have brought down so much and such coarse gravel as that of the intercalated gravel bed. Moreover, this gravel was unsorted, and at its junction with the hillside incorporated a series of massive granite boulders, which as the sketch shows (figure 2) definitely came in after deposition of the lower lake-muds. These circumstances suggested at once that the gravel might have been moved down the hillside by solifluction, and that indeed it might represent the cold phase (zone III) of the Allerød period.

With this in mind the pit was revisited in August 1936, the outline of the pit was roughly surveyed, notes were made on stratigraphy, pollen samples were secured at a site (site 36) passing through the full range of deposits, and substantial samples of the lower peat, including a monolith through the lower 'peat', were cut and stored wet until they could be analyzed for macroscopic content of fruits, seeds, etc. The map given in figure 3 shows the outline of the pit at this time, with the probable position of the 1935 peat face and the rough position of the channel carrying the lower peat bed. The letters indicate the sites of recorded profiles; these were measured and levelled, and the results are given in figure 4. It will be observed that the double structure of the peat is restricted to the depression at the northern end of the pit. Samples from the consistent wood layer at the base of the upper peat were determined microscopically to be chiefly of the genera *Betula* and *Salix*, although *Quercus* was also present. The deposits beneath the solifluction gravel in part consisted of diatomite; samples of this were sent for examination to Mr R. Ross of the British Museum, whose report upon the diatom flora is given in the appendix, and will be found to convey an impression of climatic conditions of cool-temperate character.

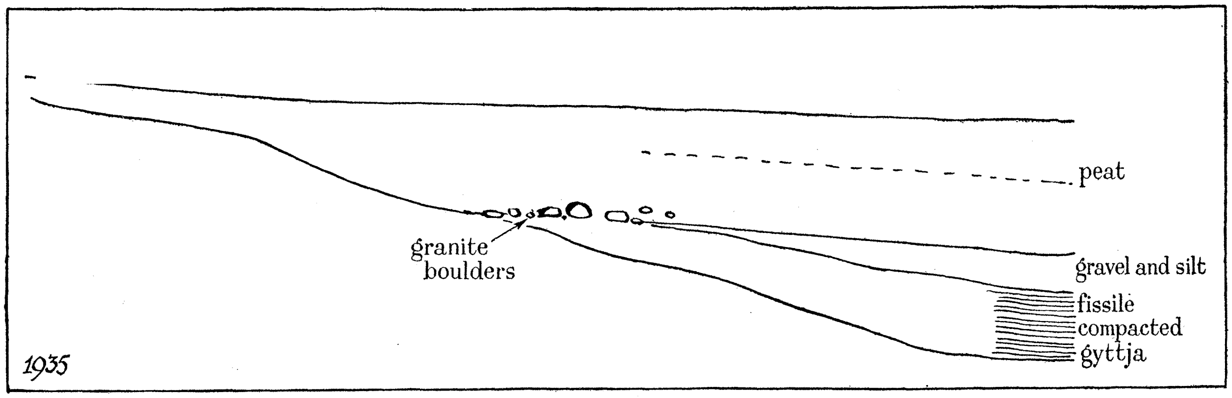

FIGURE 2. Field-sketch of peat exposure at Hawks Tor kaolin pit, 1935, showing large granite boulders brought down the hillside, presumably by solifluction, and apparently of the same episode as the gravels and silts which rest upon the laminated organic muds.

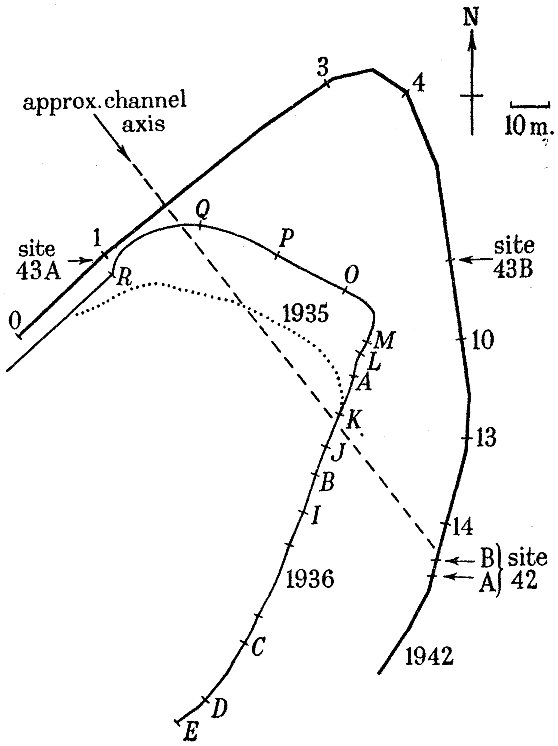

FIGURE 3. Sketch-map showing the outline of the kaolin-pit excavation (and peat-face) at the time of the 1935, 1936 and 1942–3 visits. Position of recorded profiles and sites of sampling are indicated by suitable symbols.

The pollen-analyses were undertaken by Mrs E. M. Megaw (then Miss E. M. Hardy), who supplemented her observations at this site by similar series elsewhere in the district. These results have been recorded in § 5. Her analyses clearly brought out two facts about the Hawks Tor series: (i) that the base of the upper peats contain an unmistakable early post-Glacial forest sequence, so confirming the earliness of the still lower muds and peats of the channel, (ii) that tree pollen was so scarce, absolutely and in relation to non-tree pollen, in the lower muds and peats as to support the idea that they formed in the open landscape of the late-Glacial period.

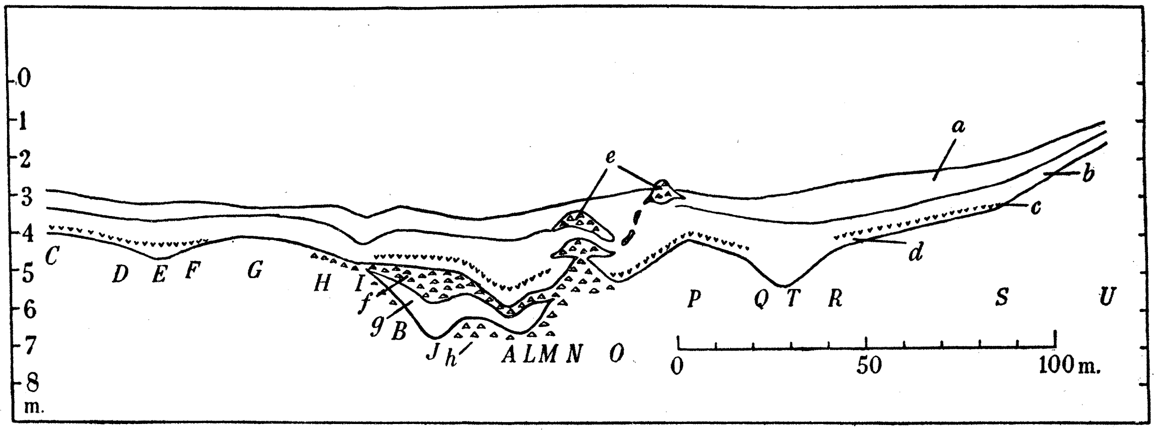

FIGURE 4. Measured and levelled profile of the organic deposits overlying the granitic gravel surface at Hawks Tor kaolin pit in 1936; vertical scale exaggerated tenfold. *a*, fresh *Molinia* peat; *b*, dark humified peat; *c*, birch-wood layer; *d*, black homogeneous peat; *e*, secondarily intruded gravel; *f*, solifluction gravel; *g*, organic muds and peats; *h*, basal gravel.

These results were already known when Miss A. P. Conolly began investigation of the macroscopic remains in the large samples collected in 1936, and her discoveries of remains of plants which to-day have a restricted northern distribution encouraged the belief that we were here dealing with deposits of late-Glacial character. It remained to determine whether or no the site shows floristic evidence for the Allerød climatic fluctuation in correspondence with that afforded by stratigraphy, pollen-analysis and diatom content. In pursuit of this aim Miss Conolly revisited the Hawks Tor pit in 1942 and 1943. She found the excavations much extended and the exposures considerably different from those seen earlier. Figure 3 shows roughly the position of the peat-face in 1942, in relation to the earlier pit outlines: as with them, letters indicate the position of records and of samples. The lower peats were fortunately still exposed and collections of material were made from them, and from the thin beds of peaty material in the gravel just above and beneath them. Many striking cryoturbatic phenomena were visible (i.e. soil movements due to freezing and thawing (Edelman, Florschütz & Jeswiet 1936)), and these are described in the text (§§ 1 *b*, 2 *b*, i, ii, iii) and recorded by photograph (figure 28, plate 25).

It was not possible to undertake a final collation of the material until 1948, by which time it had become apparent that the herbaceous pollen in the oldest layers merited much closer attention than it had received earlier. Accordingly, Miss R. Andrew, then acting as technical assistant to Dr Godwin, made a careful recount of Mrs Megaw's original slides from the lower part of the Hawks Tor series, and prepared and counted the series of samples 42A, collected by Miss Conolly through the lower peat at Hawks Tor. These supplementary counts confirmed the earlier ones, but extended them effectively by recording pollen of a number of genera now familiar in late-Glacial pollen spectra of southern Scandinavia and elsewhere.

2. STRATIGRAPHY

An outline has already been given of the general stratigraphy observed in 1936. The laboratory examination of the monolith of the lower peat taken from site 36 showed the detailed layering set out below.

(*a*) *Detailed stratigraphy, site* 36 (*Point A*)

Gravel:		Granite chips on upper face of block.
Carex-wood peat:	0 to 12 cm.	Plant detritus; numerous twigs up to 5 cm. diameter, patches of coarse tissue debris, some charred material, *Carex* nutlets abundant throughout. All much compacted with some dark brown amorphous earthy matrix. Leaf impression of *Betula nana* at 4 cm.
	12 to 16 cm.	Woody layers of numerous twigs lying in the bedding plane, some brown amorphous matrix and much plant detritus. Twigs up to 1 cm. diameter, some with whitish papery bark, others dark, shining (cf. *Salix* sp.).
Hypnum peat:	16 to 22 cm.	Light brown fibrous *Hypnum* peat, much compressed, laminated, with alternating layers of *Carex* fruits with some mud.
Carex peat:	22 to 24 cm.	Almost pure layer of *Carex rostrata* fruits with thin seams of brown lake mud and some plant detritus.
Detritus mud:	24 to 28 cm.	Brown homogeneous lake mud with muscovite, some coarse detritus and fine twigs (at 26 cm.) lying in the bedding plane, and a micaceous seam at 24 cm.
Basal kaolin gravel:	28 to 31 cm.	Angular chips of granite and fragments of quartz, felspar and muscovite in muddy matrix.

(*b*) *General stratigraphy*, 1942–3

In 1942 and 1943, when the pit was again visited, considerable extension of the excavation had been made, particularly up the valley northwards and to the east (figure 3).

At this time, the upper peat formed a continuous and almost horizontal bed over the whole extent of the exposure. It maintained a nearly constant thickness of 1·5 to 2·0 m. except to the west, where it decreased to 45 cm. with the rise of ground up the hill slope.

The lower peat was separated from the upper by a gravelly-soil deposit and rested directly on the underlying kaolin gravel. This lower peat was more restricted and irregular in occurrence than the upper; it was entirely lacking from the hill slope on the west (site 43A), and only doubtfully present on the north-west face. First clearly defined in the northern corner (point 4, figure 3), it continued all along the eastern face as a bed averaging 30 cm. thick. At the extreme southern end of the exposure there was a small channel or depression in the kaolin gravel some 18 m. across filled in with deposits of this horizon giving a maximum depth of nearly 1·5 m. (site 42, see figure 5).

On the margin of this depression, and also at one or two places on the eastern face (e.g. site 43B), disturbances and contortions of the lower peat had led to considerable irregularities and to intercalation with the gravels both above and below. This phenomenon is thought to be the result of solifluction. The upper peat beds were, however, in no way affected but lay undisturbed above.

In two places (X, between points 3 and 4; and Y, between points 10 and 13) some other disturbance of much more recent origin had jumbled up into a confused mass of broken blocks all the beds except the uppermost part of the upper peat which remained unaffected. It has not been our purpose to investigate these beds but they are clearly not part of the primary sequence of deposition: possibly they resulted from the opening of the kaolin pit itself, which initiated such sudden and rapid drainage that quantities of gravel were forced through planes of weakness in the upper peat. Alternatively they may have been similarly associated with tin-streaming. There were also in several places small, secondary, lens-shaped gravel intrusions at varying depths within the upper peat. At Z, near point 14, a recent stream-bed cut through the upper peat had been filled in with alluvial deposits (see figure 6).

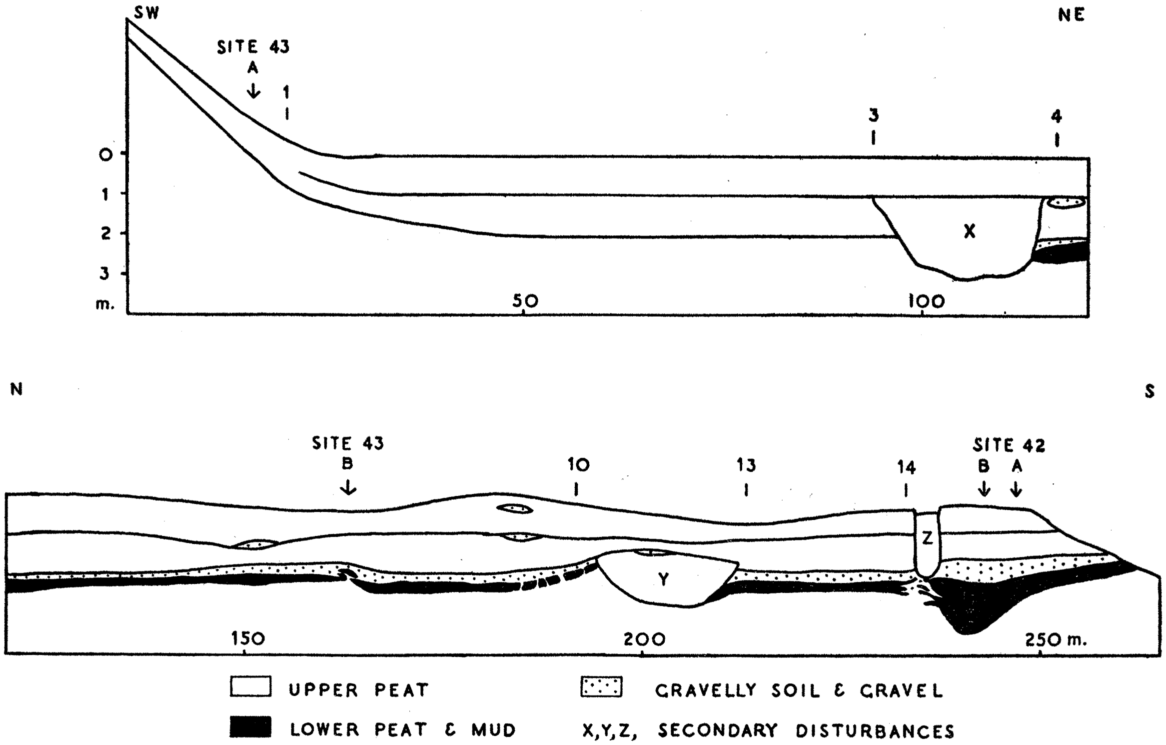

FIGURE 5. Diagrammatic profile along the exposed peat faces surrounding three sides of the pit in 1942 and 1943: above, the north-western face to the corner at point 4, and below, the eastern face from point 4 to the southern end of the peat exposures. Position of recorded profiles, photographs and sites of sampling are indicated.

The gravelly-soil deposit separating the upper from the lower peat was very variable in thickness and often not clearly distinguishable. The maximum development was at site 42, where a depth of 85 cm. was seen.

The three sites, referred to above, were chosen for more detailed consideration. Two of these, sites 43 A and B, give examples of solifluction or related phenomenon. The third, site 42, showed the maximum development of the lower peat beds; it is this site that was examined in detail for the content of plant material in the lower peat and the beds immediately above and below it.

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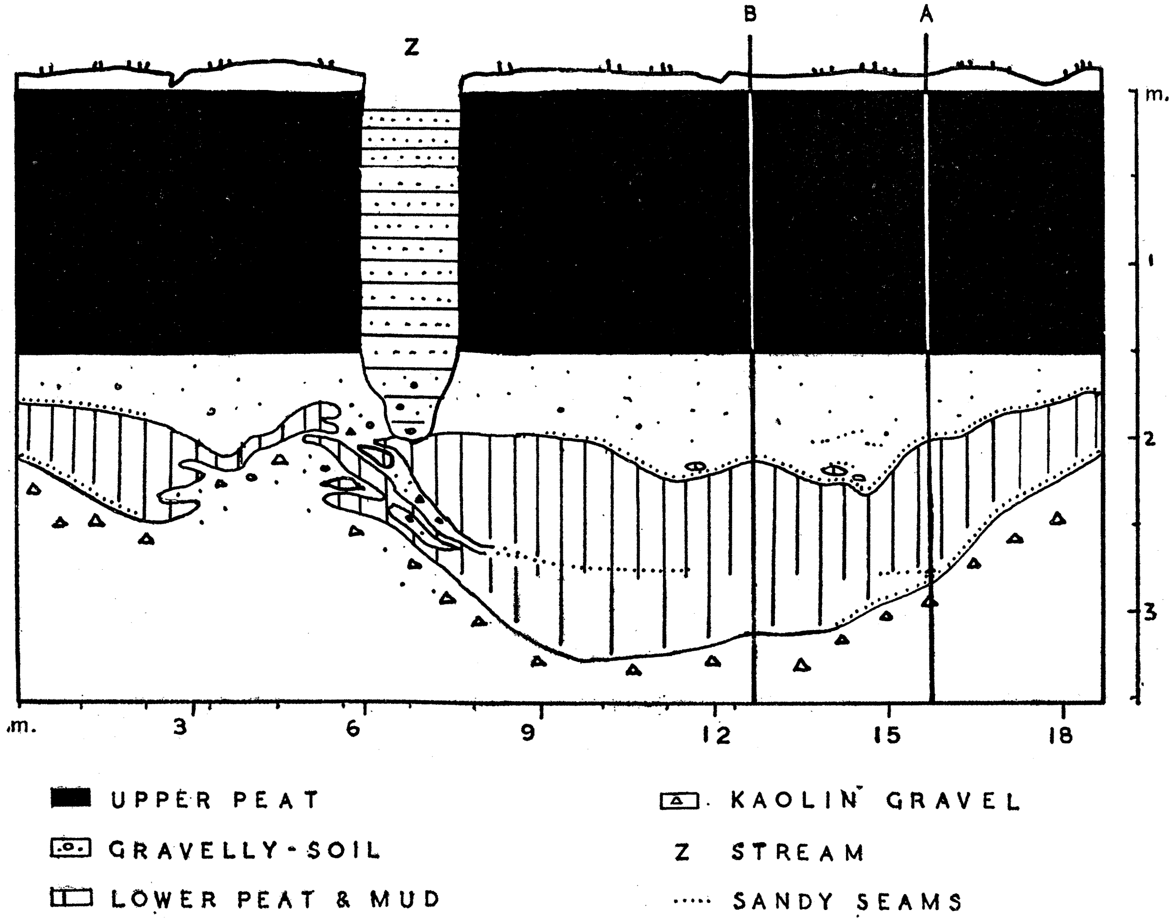

Figure 6. Diagrammatic profile of pit face in 1942 to show sites 42A and 42B. It shows infilling of the channel by the lower peat and muds, and on the left the contortion and disruption of these beds. Over these organic beds are in turn the gravelly-soil and the upper peat, the latter cut through by a recent stream channel filled with alluvium.

(i) *Site* 43*A*

Here the beds were exposed on the slope of the hill on the north-west margin of the pit. The upper peat was alone represented (50 to 70 cm. thick) and rested directly on the basal kaolin gravel; there was thus no development of the lower peat nor of any intervening gravelly-soil.

Conspicuous large granite boulders were found lying immediately beneath the peat directly on the surface of the kaolin gravel (figure 27, plate 24). They formed rectangular slabs, measuring about 100 × 60 × 25 cm., and lay on the slope of the hill, which was here about 10°. They were sharply angled and showed no indication of water transport.

Similar granite blocks were observed at various points around the exposure; always (in the exposures visible at this time) they occurred at the base of the deposits and rested on the kaolin gravel. They decreased in size towards the centre of the depression.

(ii) *Site* 43*B*

Here, on the eastern face of the pit, the sequence of beds showed a well-developed lower peat resting on the basal kaolin gravel and separated from the overlying upper peat by a gravelly-soil deposit. As shown in the photograph and diagram (figure 28, plate 25) the lower peat was here much contorted and interpenetrated by gravelly material. In places the peat had been fractured and the vertical joints gravel-filled. This phenomenon, comparable to the 'cryoturbat' of the Dutch (Edelman *et al.* 1936; Florschütz & van der Vlerk 1938), gives evidence for conditions associated with solifluction after deposition of the lower peat.

Immediately below the lower peat lay two angular granite blocks some 15 cm. in diameter; elsewhere on the eastern face of the exposure there were many such angular fragments and one (at point 13 on the profile, figures 3 and 5) measured 25 × 5 cm. in depth.

It is unlikely that these blocks, and very improbable that the boulders of site 43A, should be relics of weathering of granite *in situ*; their position is more probably due to solifluction, when, during a cold period, the alternate freezing and thawing of bare ground induced sludging movements of the thawed surface soil and boulders over the still frozen subsoil. It would thus seem very probable that solifluction phenomena occurred after the deposition of the lower peat, and very possibly also in the period immediately before.

(iii) *Sites* 42*A and* 42*B*

Detailed investigation was made at these sites on the south-east corner of the pit, for here the lower peat attained its maximum development. Consisting of muds as well as peat it completely filled the depression in the kaolin gravel, so that above the overlying gravelly-soil layer the upper peat lay horizontally across the whole section, broken only by the recent stream channel at point 14 (Z).

Notes and measurements of the stratigraphy were taken at approximately 1 m. intervals across the profile of this basin, and from these the diagram (figure 7) was constructed. Two places on the profile were chosen for detailed examination: section A on the margin of the hollow where the floor rose steeply to the south (lower peat 90 cm. thick), and section B near the deepest portion of the sediments, 4 m. to the north of A (lower peat 150 cm. thick). The actual maximum depth lay 2 m. farther north. At the northern end of the profile the floor of the depression rose steeply and the lower peat thinned to about 30 cm. It is here, on the margin of the channel, that these lower peat beds showed the extreme contortion and disturbance already referred to; in places the bed was broken into irregular blocks and was intermingled with gravel continuous with the gravelly deposits above and below. This 'cryoturbatic' disturbance, following the deposition of the lower peat beds, is even more pronounced than at site 43B.

The gravelly-soil deposit above the lower peat was here well developed. In general an upper part containing rootlets from the overlying peat could be distinguished from a lower portion without rootlets, and with a much higher proportion of granite chips. The gravelly nature of this deposit was given by these chips which, however, rarely exceeded 1 to 2 cm. in diameter. Apart from a tendency for these chips to be concentrated at certain levels one could not distinguish any order in the deposit, and these levels were themselves irregular and without horizontal continuity. Irregular, undulant sandy seams of little lateral extent also occurred. The deposit had the appearance of a rather light sandy soil which had been redeposited. In one or two places small lenses of peat had become separated from the lower peat bed underneath and were included in the base of the gravelly-soil. Fruits and seeds obtained from the gravelly-soil at this site clearly will in part at least have been derived secondarily from the peat beneath (§ 3*b*).

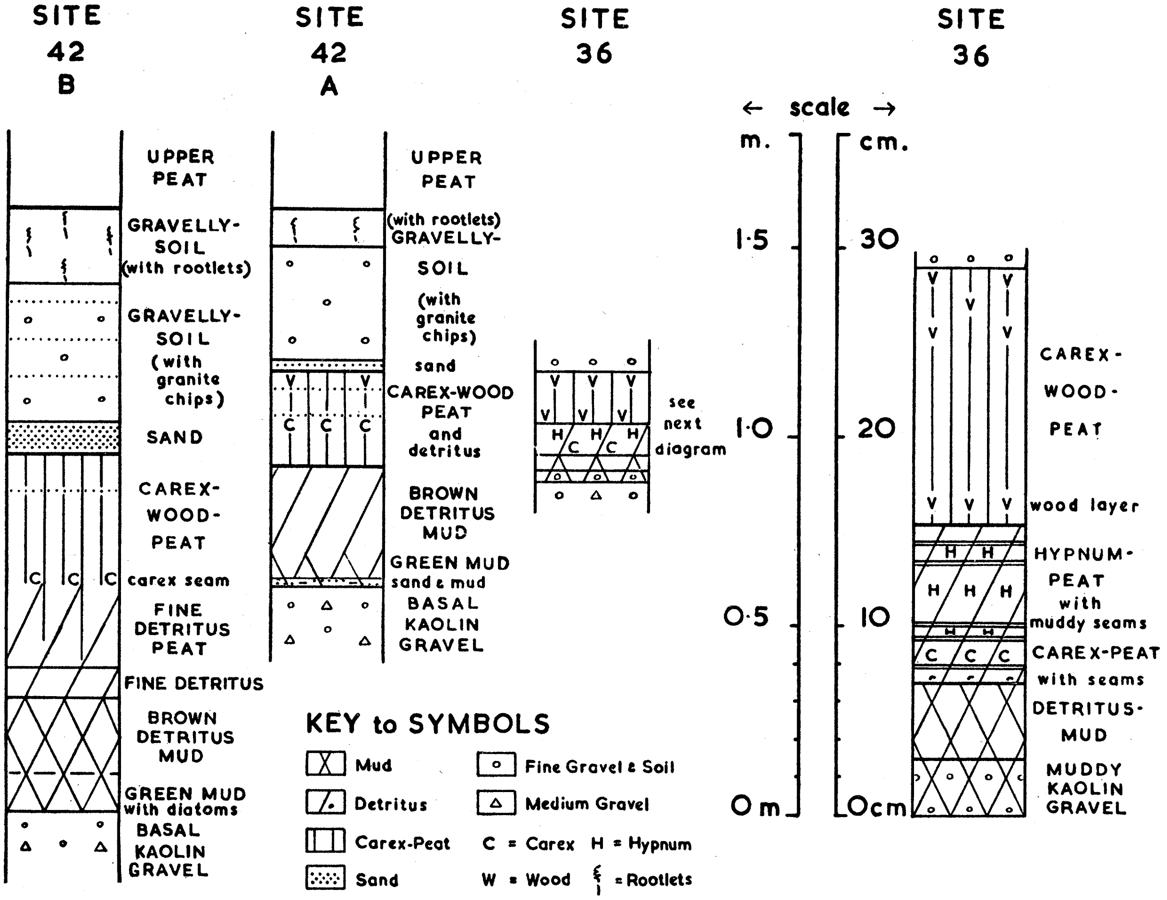

FIGURE 7. Sections through the lower beds at sites 42A, 42B and 36. The latter is shown twice, first on the same scale as the others, and secondly on an extended scale giving more detail. These sections are the sources of the macroscopic identifications of plant material in tables 1, 2 and 3; sites 42A and 36 are also the sources of the pollen-analyses shown in tables 5 and 6.

(*c*) *Detailed stratigraphy*, *site* 42

Detailed examination of the 1942 profile was made at the two points A and B on the margin of the channel and near the centre respectively. Samples were taken at various horizons and material collected for detailed laboratory investigation of the macroscopic plant content. Particular attention was given first to the muddy beds forming the base of the lower peat, and the surface layers of the underlying kaolin gravel, and secondly to the uppermost layer of the lower peat and to the gravelly-soil just above. In general, the upper portion of the lower peat was a *Carex*-wood peat like the upper layers investigated at site 36, and it was not separately examined.

In comparing the results from the two sites, 42A and 42B (set out in tables 2 and 3), it should be recalled that B lay near the deepest part of the channel, whilst A was quite high on its flank (see figure 6). It is thus comprehensible that the bottom muds from 42B are represented at A by a mere 1 cm. or so of mud, and the overlying layers are also much reduced in thickness. In figure 7 the section for site 36 is given alongside those for 42A and 42B. Besides being shown on the same scale as these, however, the section of site 36 is redrawn on a much extended scale.

(i) *Section* 42*A*

Upper peat:		Black, highly humified peat.
Gravelly-soil:	0 to 10 cm.	Brown peaty soil transitional from peat above.
	10 to 40 cm.	Brown sandy soil with granite chips scattered through lower part, vertical rootlets abundant in upper part. Sandy layer at 30 cm. and some wood at 20 cm.
	40 to 41 cm.	Micaceous sand seam.
Coarse detritus-*Carex*-wood peat:	41 to 54 cm.	Brown, fibrous detritus peat with wood above; top 2 cm. pale and micaceous. Sand seams at 54 and 48 cm.
	54 to 68 cm.	Dark stratified detritus peat with much coarse plant debris and *Carex rostrata* fruits, the latter forming an almost pure layer at 67 cm.
Detritus mud:	68 to 90 cm.	Brown organic mud with seeds of *Myriophyllum alterniflorum*, *Potamogeton*, and much plant debris.
	90 to 98 cm.	Green micaceous mud with some granite chips at 90 cm., decreasing organic content downwards.
	98 to 100 cm.	Thin purple laminated seams of micaceous sand and mud, containing leaves of *Salix* sp. and fruits of *Potamogeton*, *Viola palustris* and *Potentilla*.
Basal kaolin gravel:	100 cm.	Partly altered granite chips in a grey-white kaolin matrix; uppermost 4 cm. loosely packed, stained brown, containing vertical rootlets, fruits of *Potamogeton* spp. and *Hippuris*.

(ii) *Section* 42*B*

Upper peat:	0 to 140 cm.	Lowest 10 cm. black and highly humified.
Gravelly-soil:	140 to 160 cm.	Brown sandy 'soil' with vertical rootlets, charred fragments, twiggy debris and larger wood at 156 cm. but no granite chips.
	160 to 197 cm.	Light brown sandy 'soil' with abundant granite chips, the latter small from 185 to 197, coarse from 175 to 185, and 160 to 165 cm. with sandy bands limiting these zones.
	197 to 205 cm.	Laminated grey sand.
Carex-wood-detritus peat:	205 to 240 cm.	*Carex*-wood peat with coarse detritus, woody above with much *C. rostrata* fruit throughout and forming a pure band at 240 cm.
	240 to 262 cm.	Fine detritus peat.
Fine detritus:	262 to 270 cm.	Dark brown homogeneous fine detritus, micaceous, with a few sandy seams and fruits of *Ranunculus*, *Potamogeton*, *Montia*, and some coarse plant debris.
Detritus mud:	270 to 290 cm.	Brown micaceous fine detritus mud, lower part light olive green, with reddish mottling forming finger-like alteration zones around a core of stem or rootlets, brown above; fruits of *Potamogeton* and *Hippuris*.
Mud:	290 to 300 cm.	Homogeneous green micaceous mud, with diatoms; a single fruit of *Potamogeton* and several stamens of *Myriophyllum alterniflorum* at 294 cm., several rolled leaves of *Salix herbacea* in the bottom 4 cm. and fragments of cf. *Polytrichum* stems at the base.
Basal kaolin gravel:	300	Uppermost 2 cm. of angular rock chips ranging from minute fragments to 2 cm. diameter, in a matrix of grey-green diatomaceous mud, turning white on drying; white rootlets and branches of *Polytrichum alpinum*.

3. Identification of macroscopic plant material

The material from site 36 represented the total depth of lower peat at that point and consisted of a block of peat 29 cm. deep and 10 cm. square in section. It was divided into portions 2 cm. deep, each being separately examined. The material from site 42A consisted of small samples each treated without further subdivision; that from site 42B included a quantity of material from the basal 38 cm., treated in portions 10 cm. deep with the basal 10 cm. further subdivided into 2 cm. sections. For the most part the samples from sites 42A and 42B were restricted to the lower part of the lower peat and mud.

(*a*) *Treatment of material*

Each section of the site 36 material was split up by hand and examined for conspicuous mineral constituents, seeds or other organic remains, and was then soaked in 5 % nitric acid for from one to several days. At intervals it was stirred and the seeds and plant detritus which floated to the surface were removed. Further maceration reduced the material to a thick sludge which was sorted by sieving into several fractions. Samples from each fraction were examined under a binocular microscope and the remainder with a hand lens over a white plate. The material from site 42 was fresher and needed less treatment; the majority of seeds and organic debris floated to the surface on the addition of the nitric acid and could be removed without further sieving.

The following tables set out the results of identifying the plant material obtained in this way; in addition a great number of insect and other animal remains were recovered.

(*b*) *Identifications*

The following symbols are employed throughout the tables of results:

rr = very rare
r = rare
+ = frequent
c = common
cc = very common
a = abundant

F = fruit
S = seed
N = nut or stone
V = valve of fruit
L = leaf
* = anther cluster

W = wood
Bs = bud-scale
Sp = spore
P = fruiting perianth segment
cf = doubtful identification

Table 1. Site 36

species	remains	muddy kaolin gravel	silty detritus mud		*Carex-Hypnum* peat			*Carex* wood-peat		
		31 to 28 cm.	28 to 26 cm.	26 to 24 cm.	24 to 22 cm.	22 to 18 cm.	18 to 16 cm.	16 to 10 cm.	10 to 6 cm.	6 to 2 cm.
Batrachium	F	r	r	—	—	—	—	—	—	—
Betula nana L.	L	—	—	—	—	—	—	—	—	rr
Callitriche intermedia Hoffm.	F	r	r	rr	—	—	—	—	—	—
Carduus nutans L. or *crispus* L.	F	—	—	—	—	—	—	rr	—	—
Carex rostrata Stokes	F, N	—	r	+	a	cc	cc	a	a	a
C. echinata Mun.	F	—	—	rr	—	—	—	—	—	—
Carex cf. *nigra* (L.) Reichard	N	r	c	cc	r	r	r	rr	r	r
Carex spp.	N	rr	rr	rr	rr	rr	rr	rr	r	r
Comarum palustre L.	F	—	+	+	+	+	c	r	r	r
Eleocharis sp.	F	—	—	—	—	—	—	—	rr	—
Empetrum cf. *nigrum* L.	S	—	—	—	—	—	—	—	—	rr
Erica tetralix L.	L	rr	—	—	—	—	—	—	—	—
Hippuris vulgaris L.	N	rr	—	—	r	r	rr	—	—	—
Juncus sp.	S	—	—	—	—	rr	—	—	—	rr
Juniperus sp.	S	—	—	rr	—	—	—	—	—	rr
Lycopus europaeus L.	N	—	—	—	rr	—	—	—	—	—
Menyanthes trifoliata L.	S	—	—	—	rr	c	cc	+	—	—
Montia rivularis Gmel.	S, V	r	—	—	r	cc	+	—	—	—
Myriophyllum alterniflorum DC.	F	+	+	cc	—	—	—	—	—	—
Potamogeton alpinus Balb.	F	+	c	a	+	r	rr	—	—	—

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TABLE 1. (*cont.*)

species	remains	muddy kaolin gravel	silty detritus mud		*Carex*-*Hypnum* peat			*Carex*-wood-peat		
		31 to 28 cm.	28 to 26 cm.	26 to 24 cm.	24 to 22 cm.	22 to 18 cm.	18 to 16 cm.	16 to 10 cm.	10 to 6 cm.	6 to 2 cm.
Potamogeton cf. *densus* L.	F	—	—	rr	rr	—	—	—	—	—
Potamogeton cf. *densus* L. or *perfoliatus* L.	F	r	—	+	r	—	—	—	—	—
Potamogeton spp.	F	rr	rr	r	r	—	—	—	—	—
Ranunculus sp.	F	—	—	—	rr	—	—	—	—	—
Rhynchospora cf. *alba* (L.) Vahl.	F	rr	—	—	—	—	—	—	—	—
Salix sp.	L, W	—	—	—	—	—	—	r	—	—
Salix sp.	Bs	r	—	—	+	—	—	+	+	c
Sparganium cf. *angustifolium* Michx.	N	r	r	rr	—	—	rr	—	—	—
S. neglectum Beeby?	N	—	rr	rr	—	—	—	—	—	—
Viola cf. *palustris* L.	S	—	r	—	—	—	—	+	r	rr
Hypnum revolvens Swartz	L	—	—	—	c	cc	cc	—	—	—
Plagiochila asplenoides (L.) Dum.	L	—	—	—	rr	—	—	—	—	—
Sphagnum sp.	L	—	—	rr	—	—	—	—	—	—
Hypnum sp.	L	—	—	—	+	—	—	+	—	—
cf. *Amblystegium* sp.	L	—	—	rr	—	—	—	—	—	—
Chara	Sp	cc	r	r	rr	—	—	—	—	—
cf. *Nitella*	Sp	c	—	—	—	—	—	—	—	—
Cenococcum geophyllum	—	?	—	—	—	—	—	+	+	+

From another collection at site 36, many of the above species were also recovered, together with one seed of *Lychnis flos-cuculi* L. from the upper part of the lower peat.

TABLE 2. SITE 42A

species	remains	kaolin gravel 105 to 100 cm.	thin seams sand and mud 100 to 98 cm.	mud 98 to 91 cm.
Batrachium	F	c	r	—
Carex cf. *nigra* (L.) Reichard	N	+	—	—
Comarum palustre L.	F	r	—	—
Hippuris vulgaris L.	F	r	—	—
Montia rivularis Gmel.	SV	+	—	—
Myriophyllum alterniflorum DC.	F	+	—	c
Potamogeton alpinus Balb.	F	c	r	c
Potamogeton cf. *densus* L.	F	r	—	—
Potamogeton sp.	F	r	—	—
Rhynchospora cf. *alba* (L.) Vahl	F	rr	—	—
Rumex acetosa L.	P	rr	—	—
Salix sp.	L	—	r	—
cf. *Scirpus*	N	rr	—	—
Sparganium (*neglectum* ?) Beeby	N	rr	—	—
Veronica anagallis-aquatica L.	S	r	—	—
Viola palustris L.	S	rr	rr	—
Polytrichum alpinum Hedw.	L	—	rr	—
Chara	Sp	+	—	—
Cenococcum	—	+	—	—

Gravelly soils from site 42

From the gravelly soil at site 42 there were recovered seeds and fruits of *Carex rostrata*, *Juncus articulatus* (s.l.), *Potentilla* sp., and *Viola palustris*. They were mostly broken, and some of the *Carex* fruits were charred like those in the upper part of the lower peat, whence, in all probability, most or all of these plant remains had been secondarily derived. Wood and bud-scales of *Salix* were present, together with bark, twigs and much unidentifiable plant material.

TABLE 3. SITE 42B

		basal kaolin gravel	green mud			brown detritus mud		fine detritus
species	remains	305 to 300 cm.	300 to 296 cm.	296 to 294 cm.	294 to 290 cm.	290 to 280 cm.	280 to 270 cm.	270 to 262 cm.
Batrachium	F	r	r	r	r	c	c	c
Betula nana L.	F	—	—	—	rr	r	r	r
Callitriche autumnalis L.	F	—	+	—	r	r	—	—
C. intermedia Hoffm.	F	—	—	—	—	—	r	c
Caltha palustris L.	S	—	—	—	—	rr	r	rr
Carex rostrata Stokes	N	—	—	—	—	—	r	—
C. pulicaris L.	F	—	—	—	rr	—	—	—
Carex cf. *nigra* (L.) Reichard	N	r	rr	—	r	r	+	+
Caryophylleae	S	—	—	—	—	—	—	rr
Comarum palustre L.	F	—	—	—	r	+	+	+
Eleocharis sp.	F	—	—	—	—	rr	—	—
Eriophorum sp.	F	—	rr	—	—	—	—	—
Hippuris vulgaris L.	F	—	r	—	rr	+	c	+
Juncus sp.	S	—	—	—	—	r	r	—
Leontodon autumnalis L.	F	—	—	—	—	—	rr	—
Montia rivularis Gmel.	S	—	—	—	r	c	cc	c
Myriophyllum alterniflorum DC.	F*	—	r*	r	c*	+	c	c
Potamogeton alpinus Balb.	F	r	r	—	c	c	c	c
P. crispus L.	F	—	—	(rr)	—	+	+	—
Potamogeton cf. *natans* L.	F	—	—	+	—	r	r	—
Potamogeton cf. *natans* L. or *perfoliatus* L.	F	rr	r	—	r	—	—	—
Potamogeton cf. *pusillus* L.	F	—	—	(r)	r	—	—	—
Potamogeton spp.	F	—	—	(r)	r	r	r	r
Ranunculus flammula L.	F	—	—	—	—	—	rr	—
cf. *Rorippa*	S	—	—	—	r	—	—	—
Rumex acetosa L.	P	—	rr	—	—	+	+	r
R. acetosella L. (s.s.)	N	r	rr	r	—	—	—	—
R. aquaticus L.	P	—	—	—	—	—	cf.	r
Sagina subulata (Sw.) Presl. or *saginoides* (L.) Karst.	S	—	c	r	r	c	—	—
Salix herbacea L.	L	—	c	cf	—	—	—	—
Salix sp.	LW	—	—	—	W	—	cf.	—
Saxifraga cf. *hypnoides* agg.	S	—	rr	—	—	—	—	—
Saxifraga sp. including *granulata* L.	S	—	—	—	rr	—	rr	—
cf. *Sorbus aucuparia* L.	S	—	—	—	rr	—	—	—
Sparganium angustifolium Michx.	N	—	—	—	r	r	r	—
S. minimum (Hartm.) Fr.	N	—	—	—	rr	—	—	—
S. erectum or *neglectum* Beeby	N	—	—	—	—	r	+	+
Subularia aquatica L.	S	+	+	r	+	—	—	?
Thalictrum alpinum L.	F	—	—	rr	—	—	—	—
Typha sp.	F	—	—	—	r	—	—	—
Veronica anagallis-aquatica L.	S	—	—	—	—	a	a	a
Veronica cf. *scutellata* L.	S	—	—	—	—	—	rr	rr
Viola cf. *palustris* L.	S	—	—	—	—	r	r	r
Amblystegium serpens B. & S.	L	—	—	—	—	—	—	rr
Amblystegium cf. *filicinum* De Not.	L	—	r	—	—	—	—	—
Antitrichia curtipendula Brid.	L	—	—	—	—	—	—	+
Aulocomnium palustre Schwaeg.	L	—	c	+	+	+	—	—
Blindia acuta B. & S.	L	—	r	r	rr	—	—	—
Climacium dendroides Web. & Mohr.	L	—	—	—	—	—	—	+
Dicranum cf. *Bonjeani* De Not.	L	—	—	—	—	—	—	+
Fontinalis antipyretica L.	L	—	—	—	c	r	rr	—
Hypnum spp.	L	—	r	—	r	—	—	+
Mnium affine Bland.	L	—	—	—	—	r	—	—
Polytrichum alpinum Hedw. cf. var. *septentrionale* Brid.	L	c	c	rr	rr	—	—	—
Amblystegium or *Eurhynchium*	L	—	r	r	cf.	—	—	—
Polypodiaceae	Sp	—	—	—	—	—	—	r
Isoetes echinospora Dur.	Sp	—	—	—	rr	—	—	—
Chara	Sp	—	—	—	—	rr	c	c

4. NOTES ON THE SPECIES AND THEIR PRESENT DISTRIBUTION

The accompanying maps (figures 19, 20, 21, pp. 437–439) show the present distribution of ten species found in the Hawks Tor deposits. For six of these, *Betula nana*, *Callitriche autumnalis*, *Salix herbacea*, *Subularia aquatica*, *Thalictrum alpinum* and *Isoetes echinospora*, all localities in England, Wales and Ireland have been indicated as far as these can be ascertained from literature and herbaria; for Scotland, where these species are for the most part more widely spread, the whole of the relevant vice-counties have been filled in. For *Empetrum nigrum* and *Sparganium angustifolium*, which are widespread throughout northern Britain, the southern limit of the main area is shown, and only to the south of this are exact localities indicated. For *Polemonium coeruleum* only those localities where it is deemed truly native, or very probably so, are included; those where it is thought to be an escape, or for which there is no evidence, are excluded.

For the moss *Blindia acuta* the vice-comital distribution only is shown, without any indication of exact localities.

Areas for which a record is not confirmed either by herbarium material or by a recent locality record are vertically shaded. Extinct and dubious localities are also indicated with the date of the most recent authentic record (when known) in the former case.

Whilst endeavour has been made to make these maps complete, finality is not claimed for them.

(*a*) *Cormophyta*

Batrachium spp.

Numerous batrachian achenes were found in the lowest layers of all three sites: site 36, 31 to 26 cm.; site 42A, basal kaolin gravel and 100 to 98 cm.; site 42B, basal kaolin gravel and 300 to 262 cm., but common only in the detritus layers 290 to 262 cm. They averaged 1·1 mm. long, with some considerably smaller. All were rather flat and mostly broad relative to the length (figure 9*b*). Comparing British species of aquatic Ranunculi, *Ranunculus hederaceus* (1·3 mm. in length) would seem to come nearest; but comparable in shape also and only a little larger are *R. trichophyllos*, *R. baudotii* (both 1·5 mm. long) and several other species which differ significantly only in their larger size. In addition to the frequent occurrences recorded in the tables for the lower parts of the lower peat, these achenes were also found in the sandy seam at the junction between the lower peat and the overlying gravel (42A).

Betula nana L.

Leaf impressions (figure 8*b*) comparing closely with those of this species were recovered from the upper layers of the lower peat (site 36, 6 to 4 cm.) and several fruits (figure 8*a*) in good preservation from the lake mud at the base of the lower peat (site 42B, 292 to 262 cm.). (Measurement of the size of *Betula* pollen grains proved of no assistance in detecting a significant association of small (*B. nana*) grains with any particular level in the pollen series.)

B. nana, the dwarf birch, generally considered as of arctic affinity, is distributed in northern and central Europe, Siberia, Greenland and North America.

In the British Isles, the present occurrence of this plant is almost entirely restricted to the highlands of Scotland, where it is recorded from twelve vice-counties between Perth and Forfar, and Caithness (figure 19, p. 437). For ten of these localities are known during the last fifty years, but for (Banff and West Inverness) there seem to be no records since some time prior to 1881. The Banff occurrence is based on an old observation by Gordon (Watson 1883) and an unverified record of Dickie (1860), but it has been collected just across the county boundary (C.U. Herb. 1854). The West Inverness record is Watson's own, and his herbarium contains a specimen (presumably that referred to) collected near the same locality as that now known for East Inverness (Shoolbred 1911). A further record for Moray is very doubtful; it is neither substantiated by herbarium specimens, nor by reference to any locality, nor is it listed in the recent flora (Burgess 1935). The dwarf birch does not occur in the western islands nor Orkney and Shetlands.

FIGURE 8. *Betula nana* L. *a*, fruit from Hawks Tor, site 42B, 290 to 280 cm. (magn. × 16·6) and *b*, leaf impressions from Hawks Tor, site 36, 4 cm. (magn. × 10).

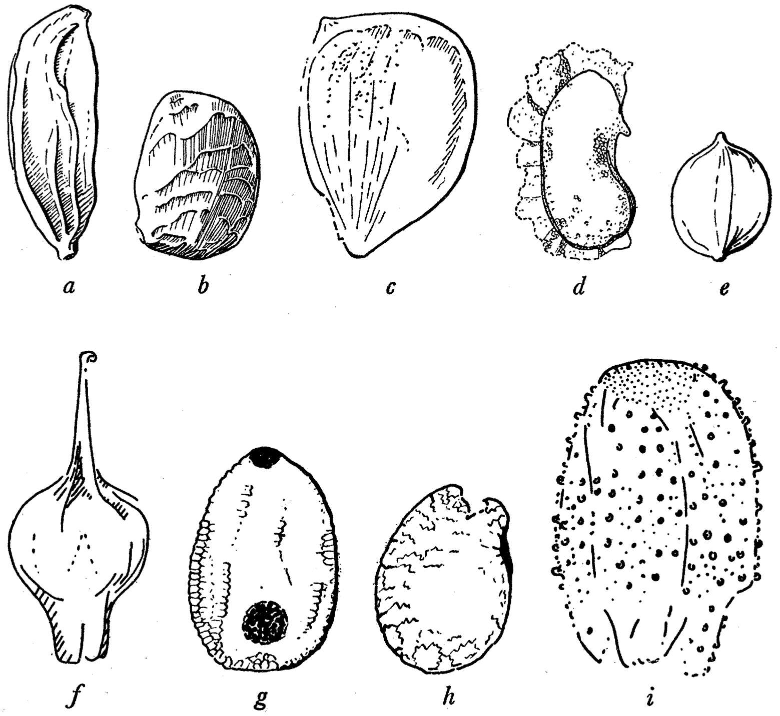

FIGURE 9. Fruits and seeds from Hawks Tor peat: *a*, *Thalictrum alpinum* L. (magn. × 13); *b*, *Batrachium* sp. (magn. × 13); *c*, *Ranunculus* sp. (magn. × 13); *d*, *Callitriche autumnalis* L. (magn. × 13); *e*, *Rumex acetosella* L. (*non sensu lato*) (magn. × 13); *f*, *Sparganium angustifolium* Michx. (magn. × 10); *g*, *Veronica aquatica* (s.l.) (magn. × 50); *h*, *Sagina subulata* (Sw.) C. Presl. or *S. saginoides* (L.) Karst. (magn. × 50); *i*, *Saxifraga* cf. *granulata* L. (magn. × 50).

All records in the south of Scotland are questionable. In Lanark, Lightfoot (1777) gave a locality subsequently repeated (Hennedy 1865) but not confirmed in recent years. For

Peebles its existence would seem to rest only on the *Exhibition of a list of plants* by Blackie (1851); and for Berwick, Watson's (1883) original query has never been confirmed. For none of these is there any herbarium specimen or recent reference.

B. nana is entirely absent from England, Wales and Ireland. A record for Cheviot is probably erroneous, for, despite its acceptance by Druce (1932), already in 1868 Baker & Tate considered this occurrence, apparently based on a single herbarium specimen, as altogether unlikely; it is now thought never to have been observed there.

In Pleistocene and late-Glacial times *B. nana* had a much more extensive and southerly range in this country. There are records, mainly of leaves, from inter-Glacial beds on the Norfolk coast (Mundesley and Beeston; Reid 1890) and from Hoxne in Suffolk (Reid 1896) and the Admiralty Office, London (Abbott 1892). From beds of later though uncertain date there are records from Yorkshire (Bridlington and Holmpton; Nathorst 1881; Reid 1885), and from Devonshire (Bovey Tracy; Nathorst 1873), as well as from the Cam Valley (Barnwell Beds; Chandler 1921) and the Lea Valley (Ponders End; Warren & Lewis 1912). Mitchell has recorded it from late-Glacial deposits in Berwickshire (Mitchell 1948) and in Co. Louth, Ireland (Mitchell 1942*a*).

Callitriche autumnalis L.

This species may be readily distinguished from the other species of *Callitriche* by the characters of the fruit. In *C. stagnalis*, the only other British species with membranous wings on the margins of the lobes, the fruit is not quite as broad as long (1·3 × 1·4 mm.) and the wing is narrow. *C. autumnalis* has larger fruit, as broad as long (2 × 2 mm.), the lobes separate much more easily and the wings are broad (Lid 1944; Butcher 1930).

The specimens of *Callitriche* from Hawks Tor (42B, 300 to 280 cm., see figure 9*d*), agree much more closely with *C. autumnalis* than with *C. stagnalis*. Only separated lobes were found, almost all with the remains of wide marginal wings. Although a little small, they must have been quite as broad as long (1·98 mm. broad × 1·7 mm. long) for the wing was incomplete.

Distributed over northern, central and south-eastern Europe *C. autumnalis* is rare and local in the British Isles, occurring in lakes and stagnant waters of northern England (not south of lat. 53° N.; Pearsall 1934), Ireland and Scotland (figure 20, p. 438).

In Wales it is confined to Anglesey, in several localities (Griffith 1895; Hyde & Wade 1934), and to a single station in Montgomery (Wade & Webb 1943). English records are from the northern counties only; the most southerly are from Cheshire (Adamson 1919; Warren, J. L. 1899) and a recent one from Staffordshire (Burges 1943–4), for which, however, the fruit lacked the wing. In Yorkshire, this species has been recorded only as adventive (Lees 1888; Cheetham & Sledge 1941). There are several localities given for west Lancashire (Wheldon & Wilson 1907), recent ones for Westmorland (Blackler 1946; Gilbert-Carter 1941), south Northumberland (Blackburn 1943–4, Harrison & Clarke 1943–4) and an old, unconfirmed one for Cheviot (Baker & Tate 1868).

In Ireland *C. autumnalis* occurs mainly in the north and north-west, but also in scattered localities down the west coast, but always very local (Praeger 1901, 1934).

Scottish records are far more numerous and come from all but seven vice-counties, and for two others (Peebles and Dumbarton) there are no good herbarium specimens. Some of the others also, are old and unsubstantiated by herbarium material, and must thus be open to doubt; as in the past, identification has been confused with *C. intermedia* Hoffm. (Pearsall 1934).

There are no records for this species from late- or post-Glacial deposits in Britain, but it is recorded from the lower *Dryas* clay (zone I) of Denmark (Allerød) (Hartz & Milthers 1901).

Callitriche intermedia Hoffm. (*C. hamulata* Koch)

Several fruit segments of another species of *Callitriche* come from sites 36 and 42 mud layers. The specimens were reddish brown (when mature), somewhat turgid, with a blunt keel, their breadth was as great as, or slightly greater than, their length, and the surface marked with a medium reticulation. In these characters they correspond with fruits of *C. intermedia*.

Of the other *Callitriche* species with small wingless fruits, *C. verna* differs in having black fruit, distinctly longer than broad and narrowed at the base, with an acute keel and the surface smooth and the markings very fine. *C. polymorpha*, whilst corresponding in several respects, such as the greater breadth than length and the surface reticulation size, has a much wider and sharper keel than in either *C. intermedia* or the Hawks Tor specimens, and, moreover, it is light in colour. Fruits of *C. intermedia* measure 1·1 mm. long and 1·2 mm. wide. This is a little longer than the specimens which are all under 1 mm., but it would seem probable that the majority at least are *C. intermedia*.

C. intermedia Hoffm. is in this country pre-eminently a plant of mountain tarns, lakes and reservoirs, and although widely distributed in lowland ponds and slow streams also, it is seen at its best in the mountains of Wales, the Lake District and Scotland, where it ascends to 3250 ft. on Ben Lawers (Pearsall 1934).

Caltha palustris L.

About half a dozen of these black shining seeds came from the mud layers at site 42B, 290 to 262 cm.

Carduus crispus L. or *nutans* L.

A single fruit measuring 2·5 mm. long came from the *Carex*-wood layer of site 36, 12 to 10 cm. Although small and collapsed, it showed the transverse wavy wrinkling characteristic of this genus. Apart from *C. tenuiflorus* Curt., which tends to have fruits of rather different proportion, it can only belong, among the British species, to *C. crispus* or to *C. nutans*. It does not appear possible to distinguish the fruit of these two species with any certainty.

Both *C. crispus* and *C. nutans* are lowland plants common, or locally common, in south Britain but thinning northwards, and perhaps not truly indigenous in Scotland (Watson, H. C. 1883); neither occurs north of Ross-shire. In Ireland *C. crispus* is mainly eastern and *C. nutans* probably only introduced. In Europe *C. crispus* is not found north of 69° 32′ N. (Norway); both also are distributed in Siberia and Caucasus, and *C. nutans* also in Turkestan, Asia Minor, Himalayas and North Africa (Druce 1932).

Carex rostrata Stokes

Very numerous nuts were found in the upper part of the lower peat, and in places formed almost pure beds: as at site 42B, 240 cm., 42A, 55 cm., and 36, 22 to 16 cm.

Here, as occasionally elsewhere, many were preserved with the inflated utricles intact, thus enabling a certain identification (figure 10). The nuts varied somewhat in form, and it is possible that some elsewhere represent other species of *Carex* which have rather similar trigonous form. In places in the *Carex*-wood layers of site 36 the nuts were charred. In the gravelly-soil deposit overlying the lower peat there were several nuts of this species, some carbonized.

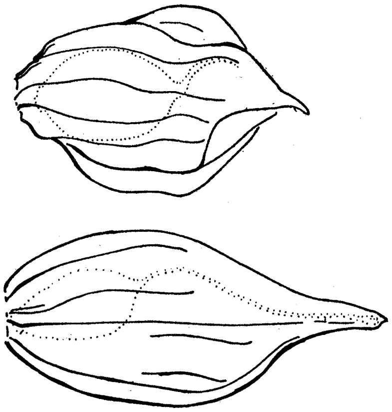

FIGURE 10. *Carex rostrata* Stokes. Fruits with utricles from Hawks Tor, site 36, 7 to 9 cm. (magn. × 10).

Carex pulicaris L. and *C. echinata* Murr.

A single fruit of the former and two of the latter species were found in excellent state of preservation. The utricles were intact in both; *C. pulicaris* had the remains of the curved stalk, and *C. echinata* showed the veins and the long-toothed bifid beak.

Carex spp.

Apart from the trigonous nuts, included under *C. rostrata*, there were numerous flat ovoid or obovoid nuts. Some of these may well be *C. nigra* (L.) Reichard, but other species are certainly represented.

Eleocharis

A small nut resembling *E. palustris* came from the site 42B mud. As not sufficient of the swollen style base was preserved, and in view of the very small size of the fossil nut, this can only be a tentative determination.

Empetrum nigrum L.

One nut recovered from the uppermost layers of the lower peat, site 36, 6 to 2 cm., may be referred to *E. nigrum* L. or to *E. hermaphroditum* (Lange) Hagerup. Pollen was identified from site 36, 0 cm., site 42A, 45, 60, 70 cm. (see § 5*e*).

E. nigrum L. (figure 20, p. 438) is distributed in the British Isles mainly in the west and north, decreasing or absent from the south and east. In the south of England it is now confined to Dartmoor and Exmoor (north and south Devon, and Somerset) at altitudes of generally over 1500 ft. (Martin & Fraser 1939), but until last century it also grew in Dorset (Good 1948) and Sussex.

To the west it occurs throughout Wales (except Pembroke and Anglesey) and in the Welsh Border counties (Hereford and Salop). East of this there are isolated stations in four counties:

Warwickshire: a single station (Sutton Coldfield) in the extreme north-west on the Staffordshire border, where it was still abundant in 1891 (Bagnall).

Leicestershire: known until recently very sparingly in one locality on Charnwood Forest at 700 ft. (Horwood & Noel 1933; Herbarium specimen of 1915). Now probably extinct.

Nottinghamshire: limited to the 'Bunter' area where it persisted in 1904 (Carr).

North Lincolnshire: formerly in Axholme Island in the north until 1895, and at Friskney and Wainfleet Tofts in the south (Woodruffe-Peacock (*c.* 1920)).

North of these localities, *E. nigrum* occurs on Cannock Chase and several places in north Staffordshire (Bagnall 1901), becoming abundant on the Pennines of north Derbyshire, and occurring in all vice-counties to the north, except south-east Yorkshire, where it may once have grown (Cheetham & Sledge 1941). It occurs abundantly throughout Scotland where it descends to sea-level; it is widespread in Ireland.

E. hermaphroditum (Lange) Hagerup is now known to occur in this country, and some of the more northern localities for *E. nigrum* may in fact refer to this species: it has been recorded from Wales (Snowdonia), northern England and from several parts of Scotland. Outside Great Britain it ranges considerably farther north, to 79° N., as opposed to 63° N., and also occurs on the high alps of Europe.

E. nigrum is known from the Irish late-Glacial at Ballybetagh, near Dublin, zones II and III (Jessen & Farrington 1938). Jessen (1949) has pointed out that the pollen of *E. nigrum* can be distinguished by its smaller size from that of *E. hermaphroditum*, and refers the abundant *Empetrum* pollen of the late-Glacial in Ireland to *E. nigrum* L.

The pollen (see § 5*e*) comes from the *Carex*-wood peat, or from the junction of this with the gravelly-soil, or from the gravelly-soil itself. This corresponds with the position at which the stone was found at site 36. The pollen size indicates that this also was *E. nigrum* L.

Erica tetralix L.

A single leaf, measuring 2·3 mm. with inrolled margins and prominent (glandular) hairs was found in the extreme base of site 36. With it was a minute triangular leaf or bract with similar glandular hairs. Comparison with leaves of British Ericaceae would suggest the leaf to be that of *E. tetralix*.

Eriophorum

A single, unripe fruit, flat and rather smaller than average for *E. angustifolium* (i.e. only 1·6 mm. long) is tentatively referred to this species.

Hippuris vulgaris L.

Many of the characteristic fruits (mericarps) of this species, associated with those of *Myriophyllum alterniflorum*, came from site 42B in the mud and detritus layers; a few were also found in the basal kaolin gravel (42A, 36) and at site 36 in the *Carex-Hypnum* peat. Although not recorded from east Cornwall to-day, this species is known from most areas in Britain; it is commoner in the north.

Isoetes echinospora Dur. (figure 20, p. 438)

A single macrospore came from the lower muds of site 42B, 296 to 290 cm. It had many projecting marginal spines with frayed, almost barbed, tips where they had doubtless been broken off. The surface was covered with oval and circular markings, the bases of spines of which some could be distinguished. There is little doubt that this specimen is *I. echinospora*, for although macrospores of some other species have spines these are restricted to the marginal ridges and are short and broad, as in *I. lacustris*. In *I. echinospora*, but in no other species, these spines are long and slender and cover the whole spore surface.

In the British Isles this species is regarded as Scottish, occurring in alpine and subalpine pools (Druce 1932). Isolated occurrences have, however, recently been recorded from the south of England; from Dorset (Hall & Salmon 1928), from Dartmoor, and from Bodmin Moor itself (Oldham 1934). In Wales there are records from Glamorgan, Merioneth and Caernarvon; and from Ireland it is known in the west from southern Kerry to western Mayo (Praeger 1934). In Scotland there are several stations from Dumbarton north to west Sutherland. The general distribution for this species is north and central Europe; Iceland; North America; Greenland (Druce 1932).

Juncus spp.

Four seeds from the upper muds of site 42B compare in size (0·56 mm. long) and in surface pattern with the group containing *J. articulatus*, but to which species of this group it is not possible to say. A few seeds were also found in site 36, 22 to 18 cm. and 6 to 2 cm., and also in the upper part of the gravelly-soil deposit overlying the lower peat; they were frequent in the sandy seam at the junction of these two beds at site 42A.

Juniperus

Several rather irregular nuts or stones with flat longitudinal faces but without definite ribs may be of this genus; one specimen from site 36, 6 to 2 cm., at the top of the lower peat corresponds sufficiently with stones of juniper to merit listing.

Leontodon autumnalis L.

A single achene corresponding in size and the nature of the ribbing with this species came from site 42B, 280 to 270 cm.

Lycopus europaeus L.

One labiate nut with the marginal border characteristic of this species was found in site 36, 24 to 22 cm.

Menyanthes trifoliata L.

The flat circular seeds of *Menyanthes* were readily recognized, even when undeveloped or fragmentary, by the cellular surface pattern. They occurred most frequently in the upper part of the *Carex-Hypnum* peat of site 36.

Montia rivularis C. C. Gmel. (*M. lamprosperma* Cham.)

Numerous seeds of *Montia* (figure 11*a*) were recovered from the *Carex-Hypnum* peat of site 36, 29 to 26, 24 to 16 cm.; site 42A, in the basal kaolin gravel; and site 42B, in the mud and detritus between 294 and 262 cm. They were particularly common in the *Carex-Hypnum* peat of site 36 and the uppermost muds of site 42. Scattered pollen grains of *Montia* were identified from sites 36 and 42A (see tables 6, 7, pp. 448 and 450); they mostly occur in the lower peats and muds. Many curious bract-like objects, nearly all occurring singly but a few in pairs, were found to be the valves of *Montia* capsules; they consisted of only a single layer of cells which, except at the base, were long and sinuous (figure 11*b*, *c*, *d*). They occurred at site 36, 22 to 18 cm.; site 42A, basal kaolin gravel; and site 42B, 294 to 262 cm. (especially numerous, 270 to 262 cm.).

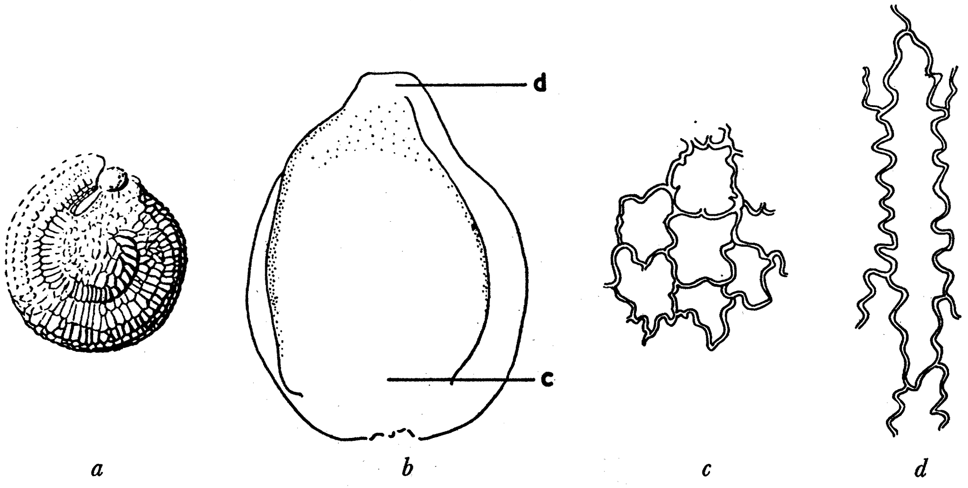

FIGURE 11. *Montia fontana* L. (s.s.). *a*, seed from Hawks Tor, site 36, 22 to 20 cm. (magn. × 25); *b*, valve of capsule (magn. × 25); *c*, *d*, cells from apex and from centre of capsule valve (magn. × 250); *b*, *c* and *d* from Hawks Tor, site 42B, 270 to 262 cm.

The three forms of *Montia* in this country have been included in the aggregate species '*Montia fontana*', but they may be clearly distinguished by seed characters:

M. verna Necker = *M. fontana* α *chondrosperma* Fenzl has the seeds covered all over with coarse tubercles; they are dull, usually brownish black, and measure 0·6 to 1·2 mm. in diameter (Butcher 1930).

M. rivularis C. C. Gmel. (including *M. lamprosperma* Cham.) has seeds that are reticulate but not tuberculate (except rarely on the keel), and in the northern form (*M. lamprosperma*) they are strongly shining over the whole surface, and black in colour (Moss, 1920; Druce 1908); they measure 0·8 to 1·3 mm. in diameter (Butcher 1930). This geographical form of the north with very smooth shining seeds described as *M. lamprosperma* by Chamisso is not, according to Hylander (1945), considered to be specifically distinct from the central European *M. rivularis* of Gmelin. Thus its valid name must be *M. rivularis* despite its possible separation as a subspecies.

A third form described as *M. fontana* var. *intermedia* Beeby (1909) is most probably a distinct species. In this form the black seeds bear three rows of conical tubercles on each side of the minutely tuberculate dullish keel, and the sides are reticulate and shining (Clapham, Tutin & Warburg 1950; Moss 1920).

The *Montia* seeds from Hawks Tor agree in their reticulation and the absence of tubercles with those of *M. rivularis* Gmel. They measure 0·9 to 1·1 mm., and the majority are black and shining as in Chamisso's northern '*lamprosperma*'; it is to this form that they are referred.

M. rivularis Gmel. is a central European species, but '*M. lamprosperma*' has a more northerly distribution than this or *M. verna*. According to Ostenfeld (1908) it is the only form found in the Faröes; it is the plant of Greenland, Iceland, Scandinavia and also occurs in northern Russia, Finland and Pomerania. In Britain it is mainly a northern species thinning out southwards (Druce 1932). The general southern limit in England and Wales, apart from an outlier in Surrey (Salmon 1931), lies from Glamorgan, Brecon and Shropshire to the west, to Derby, Nottinghamshire and south-east Yorkshire to the east. North of this it is of general occurrence.

Irish localities are scarce, due partly to the segregates not having been distinguished. The most southerly records are from north Kerry (Druce 1911; Scully 1916) and Clare (O'Kelly 1915) on the west coast, and Armagh (Druce 1932) and Down (Stewart & Corry 1938) on the east.

Fossil occurrences under '*M. fontana*' may refer to *M. rivularis*, i.e. *M. lamprosperma* Cham., or to *M. verna* Necker; such are those from deposits at Clacton-on-Sea (Warren, Reid & Chandler 1923*b*), Allenton, Derbyshire (Arnold-Bemrose 1896) and the Lea Valley at Hedge Lane (Reid 1915).

Myriophyllum alterniflorum DC.

Numerous fruits agreeing in their small size and lack of tubercles with those of *M. alterniflorum* came from the basal layers, the kaolin gravels and the lower muds (see tables 1, 2 and 3). From the lower muds of site 42B several stamen clusters were washed out, and in one case, two anther clusters were still attached to a short stalk (figure 12*a*). By extracting the pollen from one of these it was possible to identify them as *M. alterniflorum* (figure 30, plate 25). Pollen in very large amount was counted from the lower layers of the lower muds and peats at both site 36 and site 42A (see tables 5 and 6). Although not

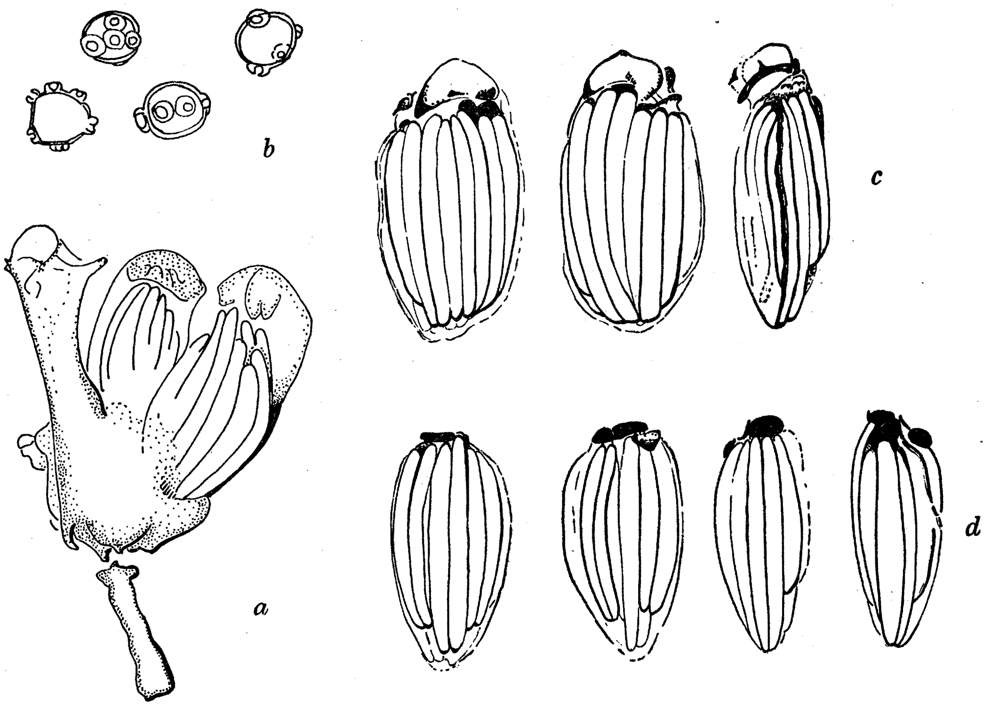

FIGURE 12. *Myriophyllum alterniflorum* DC. *a*, flower with anther clusters (magn. × 25); *b*, pollen grains (magn. × 500); *c*, dorsal, ventral and lateral views of one anther cluster (magn. × 25); *d*, dorsal, ventral and two lateral views of another anther cluster (magn. × 25). Hawks Tor: *a*, from site 42B, 296 to 292 cm.; *b* and *c* from site 42B, 298 to 296 cm.; *d* from site 42B, 300 to 298 cm.

restricted to the oldest deposits, this pollen in large amount is extremely characteristic of the oldest post-Glacial ('pre-boreal') layers of north-west European deposits. It occurred in zone IV at Southampton (Godwin & Godwin 1940).

Polemonium sp.

One pollen grain of a *Polemonium* was identified from site 36, 24 cm.

Of the European species of *Polemonium*, *P. coeruleum* L. and *P. boreale* Adams, it is not possible to say to which the Hawks Tor pollen belongs. Of these species only *P. coeruleum* is known from Great Britain, and as a native has now a very restricted range (figure 21, p. 439). The majority of localities occur on the limestone scars and screes of the Craven uplands of west Yorkshire (Lees 1888; Cheetham & Sledge 1941), and of Derbyshire (Linton, W. R. 1903; Hall, F. T. & R. H. 1939–40), with extensions into Staffordshire (Bagnall 1901; Boydon-Ridge 1931) and Leicestershire (Horwood & Noel 1933). *Polemonium* was at least known formerly, from Upper Teesdale (Backhouse 1843–4) and from the Cheviots (Baker & Tate 1868). In Wales it is deemed native in two stations, Denbigh and Flint (Hyde & Wade 1934). Elsewhere this plant is probably only an escape from cultivation. There are records from several counties from Cornwall to Sussex and north at least to Perthshire. It is not known native in Ireland.

Beyond the British Isles *P. coeruleum* occurs in north and central Europe (Scandinavia, Pyrenees, Alps, Carpathians), Caucasus, Siberia and North America; whereas *P. boreale* is an arctic plant of Spitzbergen, Finnmark, North America and Asia.

Potamogeton alpinus Balb.

The majority of the small fruits of this genus belong to *P. alpinus*; they varied somewhat in size, and many had the keel portion separate. These fruits were particularly abundant in site 36, 5 to 7 cm., and were common throughout the lower muds.

Potamogeton densus L., *P. crispus* L., etc.

Of the larger *Potamogeton* specimens, one from site 36 (26 to 24 cm.) was clearly *P. densus*, for the shining jacket with its wide acute keel was still intact. Other specimens from this layer showed the remains of a shiny coat and are most probably referable to the same species. Many others had no cover left, and thus, though possibly also *P. densus*, could equally belong to *P. perfoliatus* L.; or, indeed, both species may be present.

Of the very small specimens it seems likely that several from site 36 are *P. coloratus* Hornem.

From site 42B mud and detritus layers, besides numerous specimens of *P. alpinus*, there were also several of the characteristic large fruits of *P. crispus* with the long beak and jagged keel still preserved. Other large specimens, with round outline and shallow umbilicus and without the jacket, were more difficult to compare; the largest (from the 296 to 294 cm. layer) approach *P. natans* L., but others, similar in form but smaller, though possibly small specimens of *P. natans*, might be *P. densus* or *P. perfoliatus*; others again are not sufficiently well preserved to exclude the possibility of still further species being represented.

Several of the smallest specimens from site 42B compare favourably with *P. pusillus* L. (292 to 290 cm. layer); others recall *P. coloratus* or possibly *P. polygonifolius* Pourr. (290 to 270 cm.).

Ranunculus flammula L.

A single achene corresponding fairly closely to those of modern *R. flammula* came from the upper mud of site 42B, 280 to 270 cm.; although rather larger than average (1·6 mm. as compared to 1·4 mm. for recent *R. flammula*) it is not beyond the range of the latter (1·75 mm.). The closely allied *R. reptans* L. has fruit distinguished by the hooked beak (unfortunately the beak is missing from the Hawks Tor specimen), and it is smaller (1·3 mm.); the northern form *R. scoticus* E. S. Marshall has achenes similar in size (according to material available) as well as in shape to the specimen, and it is not impossible that it is this form here represented.

Ranunculus sp. (figure 9*c*, p. 414)

The mud layers of site 36, 24 to 22 cm., contained a single achene of a *Ranunculus* not readily referred to any British species. It is pitted, with a raised margin rather like that in *R. lingua*, but it is smaller than this species (i.e. only 1·9 × 1·4 mm.) and flatter and more circular in outline; in the latter respect it resembles the form shown in *R. acris*, *R. bulbosus* or *R. repens*, but it is very much smaller and paler in colour than any of these species.

Rorippa or *Nasturtium*

Remains of a very small cruciferous seed (under 1 mm. long) from the lower muds of site 42B showed a rather coarse net-like testa resembling that found in the two genera *Rorippa* and *Nasturtium*. This reticulation is of about the same dimensions and appearance as appear on the seeds of *N. officinale* (tetraploid) R.Br. and of *Rorippa silvestris* (L.) Besser. However, in size the specimen is considerably smaller than *Nasturtium officinale* seeds and a little shorter than those of *Rorippa sylvestris*; moreover, it is considerably narrower than in this species. Other fragments of detached reticulum all suggest a very narrow seed, and it is possible that the species represented is not now in Britain.

Rumex acetosa L.

A complete fruiting perianth segment from the base of the deposit at sites 42A and 42B showed the undulant epidermal walls characteristic of the *acetosa* section of *Rumex*. From the perianth alone it is not possible to say whether the specimen should be referred to *R. acetosa* in the strict sense or to one of the related species (Löve 1944). Several similar though less well preserved perianth segments came from the upper mud and detritus layers of this site (42B).

Rumex acetosella or *R. tenuifolius* (Wallr.) Löve (figure 9*e*)

Several nuts clearly belonging to the subgenus *R. acetosella* were found at the extreme base of the profile at site 42B, both in the top of the underlying gravel and in the lowest mud layers (300 to 294 cm.). They were mostly black (a few brown) with a high polish. The smooth surface revealed minute reticular-cellular markings, characteristic of this genus, but no trace of perianth segments. They ranged in size from 0·98 to 0·84 mm. long and 0·77 to 0·70 mm. wide, with an average of 0·88 × 0·75 mm.

The aggregate species *R. acetosella* has long been known (Balansa 1854) to consist of two forms distinguished by the fruit: one with the fruiting perianth segments readily separable from the smooth shining nut, and the other with them closely adhering to the nut and falling with it as a unit. Čelakowski (1892) named them var. *gymnocarpus* and var. *angiocarpus* respectively; but Murbeck (1891), regarding them as distinct species, gave the name *R. angiocarpus* to the latter and retained the Linnean name *R. acetosella* for the gymnocarpic form. Recently, Löve (1940, 1941 *a*, *b*) has not only shown these two species to be genetically distinct but further distinguishes two more gymnocarpic species, *R. tenuifolius* (Wallr.) Löve and *R. graminifolius* Lamb. All four differ in size and shape of the nut, that of *R. angiocarpus* with the fused perianth segments removed is the smallest; it measures 0·96 × 0·96 mm.; of the three gymnocarpic species the nut of *R. tenuifolius* is about 1 mm. long (0·9 to 1·3 mm.) and 0·7 mm. wide (0·6 to 0·8 mm.); in *R. acetosella* L. it is bigger, about 1·5 mm. long (1·3 × 1·8 mm.), and in *R. graminifolius* 1·76 × 1·0 mm.

The nuts from Hawks Tor must belong to one of the gymnocarpic species, for there is no sign of any adherent perianth on any of the specimens. It is not thought likely that this is due to loss of preservation; nuts of *R. angiocarpus* with the adherent perianth have been previously reported (Conolly 1941, figure 4 as *R.* '*acetosella*'). Of the three gymnocarpic species, *R. graminifolius* can be excluded because of the large size of its nuts. This leaves *R. tenuifolius* and *R. acetosella* L. as possibilities for the Hawks Tor specimens, and although the latter fall within the size range for *R. tenuifolius* and are smaller than well-developed *R. acetosella* they may belong to either species.

Since Mr Lousley is at present working out the British distribution of this group of species it would be pointless to attempt a statement now beyond the fact that both *R. tenuifolius* and *R. acetosella* tend to be absent from the south of this country.

In Europe both are absent from the west and are common in the north, but *R. tenuifolius* alone reaches the extreme northern latitudes, and *R. acetosella* is found farther south, in Italy and the Balkans where the other is not known, as well as extending into the Orient.

Fossil records of '*R. acetosella*' cannot be regarded with certainty as belonging to *R. acetosella* L. in the strict sense; these include those from the Clacton-on-Sea inter-Glacial bed (Warren *et al.* 1923 *b*), the Lea Valley (Ponders End) (Reid 1915) and the Irish late-Glacial (zone III) at Ballybetagh and Ralaghan, Co. Cavan (Jessen & Farrington 1938).

Rumex aquaticus L. non auct.angl.

A single complete fruiting perianth from the upper part of the lake mud, site 42B, 270 to 262 cm. (figure 13), may be referred with certainty to this species, and further portions with some probability.

In the complete specimen both inner and outer whorls of the perianth were present, at least four stamens, and an almost ripe nut. The inner perianth segments were very slightly cordate at the base and rather broad; but as the upper part was not complete the original shape may have been either ovate or subcordate. There was no sign of a tubercle on any of the segments. Enough of the margin remained to show that it was almost entire with a few blunt teeth. The reticulate venation was strongly marked; the angles between the secondary veins and the primary ones were obtuse at the base and acute above. The epidermal cells were rectangular, small polygonal. The dimensions of the inner perianth segments were 5·75 mm. width, 5·25 mm. remaining length, and of the nut 3·75 × 2·1 mm.

Only three of the European species of *Rumex* with perfect flowers have all the three inner perianth segments devoid of the tubercle; they are *R. aquaticus* L., *R. longifolius* DC. (= *R. domesticus* Hartm.) and *R. alpinus* L. The inner perianth segments of both the two latter species have a *deeply* cordate base, and the lower as well as the upper secondary veins make an acute angle with the primary. *R. aquaticus*, on the other hand, has a *truncate* base to the inner perianth segments and, moreover, in the lower part the secondary veins form an *obtuse* angle with the primary. In both these characters the specimen from Hawks Tor agrees with *R. aquaticus*. The general size, shape and nature of the margin of the fruiting perianth also conforms with descriptions of *R. aquaticus* (Lousley 1939; Ascherson & Graebner 1912), and in particular the venation compares very closely with that of recent specimens (figure 13*e*, *f*) which illustrate the two varieties described (*R. hippolapathum* and *R. heleolapathum*) (Rouy & Foucaud 1910). From this it seems safe to conclude that the specimens belong to *R. aquaticus* L. This identification has been kindly confirmed by Mr J. E. Lousley.

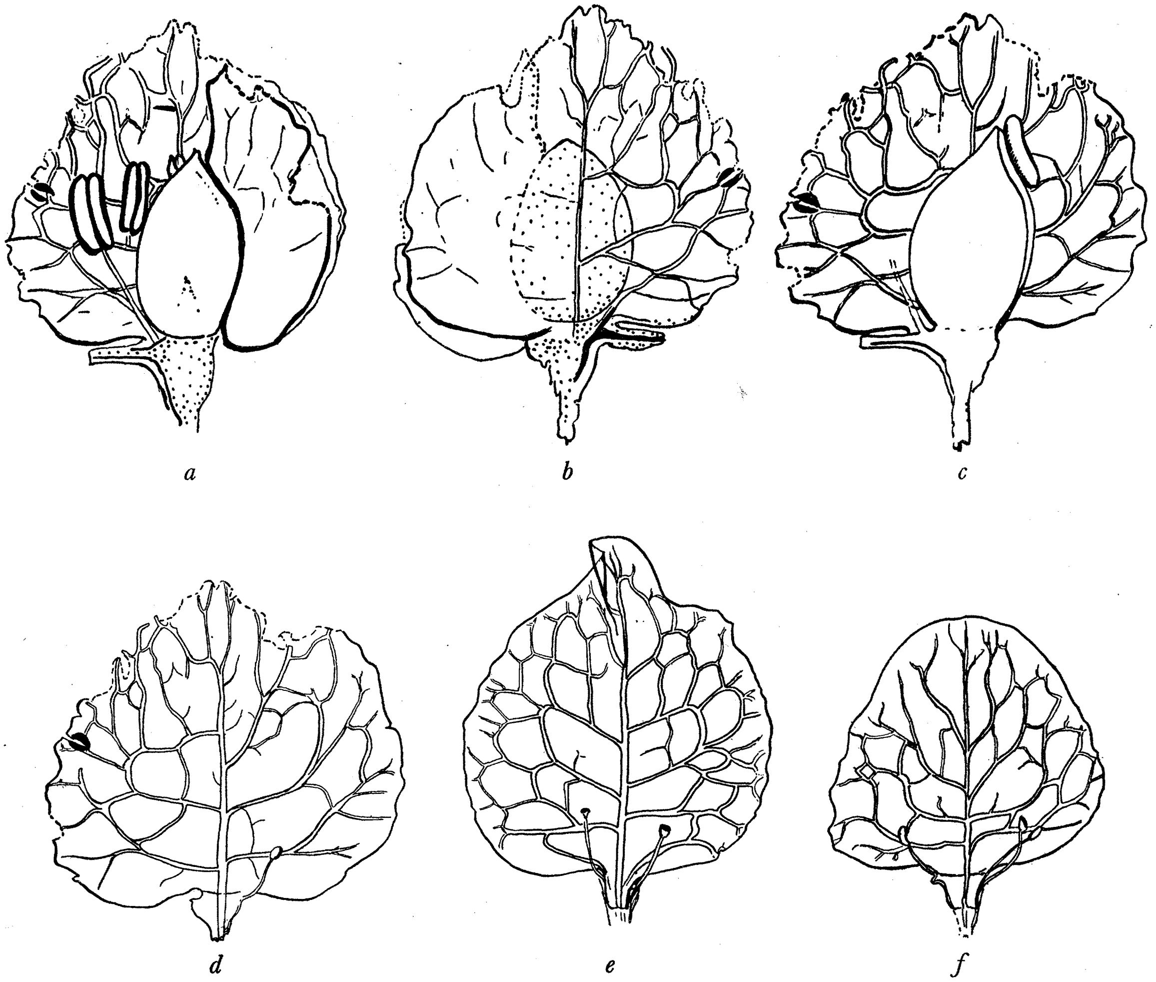

FIGURE 13. *Rumex aquaticus* L. non auct.angl. *a*, *b*, *c*, three different views of almost complete flower: *a*, showing three fertile stamens and nut: one inner perianth segment missing; *b*, reverse view to *a*; *c*, same view as *a* after removal of second perianth segment, one stamen remaining attached; *d*, posterior inner perianth segment with one sterile stamen from same flower. Hawks Tor, site 42B, 270 to 262 cm. (magn. × 8). *e*, *f*, inner perianth segment from flowers of *Rumex aquaticus* L. non auct. angl.: *e*, from Herbarium material '*R. Hippolapathum* Fries., Herb. Nov. Suec. f. 5, no. 55'; *f*, from Herbarium material '*R. Heleolapathum* Drej.' (magn. × 8).

R. aquaticus L. has a wide range in Europe, though in the west it is only scattered. It is absent from the southern part of the Balkan Peninsula and Italy south of the Tyrol. It extends through northern Asia to Siberia, but not to North America; in Europe north to Finnmark (Lid 1944). In the British Isles, this plant is known only from the shores of Loch Lomond, where it was found by Mackechnie in 1935 (Lousley 1939). All previous records were erroneous and refer to *R. longifolius* DC., to which the name '*aquaticus*' has been in the past misapplied by British authors.

Two perianth segments agreeing fairly well with *R. aquaticus* L. have been found from late-Glacial mud at Ballybetagh, near Dublin, Ireland (Jessen & Farrington 1938), but no other fossil occurrence is known from the British Isles.

Sagina subulata (Sw.) C. Presl or *S. saginoides* (L.) Karst. (figure 9*h*)

A great number of the minute seeds of this genus came from the lower part of the lake mud (site 42B, 300 to 280 cm.). From the size, and from the pattern of the testa, they belong either to *S. subulata* (Sw.) C. Presl or to *S. saginoides* (L.) Karst.; on the whole they are rounder and less elongate than usual in *S. subulata*, but there are not sufficient constant differences between the seeds of these two species to warrant a definite decision between them.

S. subulata is a local plant in Britain, found in the south, in the west of Wales, in north-east England, and in Scotland, where it is frequent; in Ireland it is coastal in the north and west.

S. saginoides, however, is restricted to a few areas in highland Scotland. Elsewhere *S. subulata* is alone found in south Europe, and does not go far north—to 65° in Norway (Lid 1944)—whereas *S. saginoides* is found in the Arctic and in Iceland and Greenland as well as alpine Europe.

Salix herbacea L.

Numerous leaves in excellent state of preservation were obtained from the lowermost layers of the lake mud at site 42B, 2 to 4 cm. (figure 14).

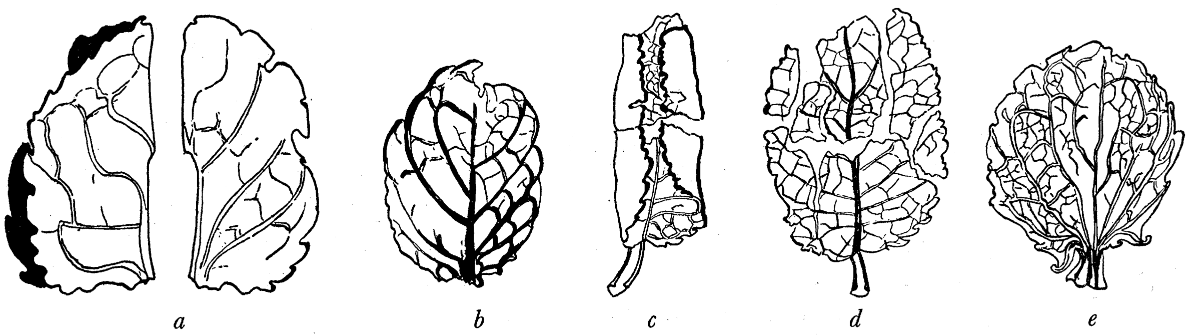

FIGURE 14. *Salix herbacea* L. Leaves from Hawks Tor, site 42B: *a*, 298 to 296 cm. (magn. × 6); *b*, 300 to 290 cm. (magn. × 5); *c*, *d*, 298 to 296 cm. (magn. × 3); *e*, 298 to 296 cm. (magn. × 6).

S. herbacea is a characteristic member of Watson's highland type, and is considered by Polunin (1939) as truly arctic. It ranges throughout the arctic and northern regions of Europe, Asia and North America (Linton, E. F. 1913), as well as the central European mountains. In the British Isles it is locally common on the summits of the higher mountains (figure 19, p. 437).

In Wales it is found chiefly in Snowdonia, and also on Cader Idris, Plynlimmon (Salter 1935), Carmarthen Fan (Ley 1908) and the Brecon Beacons at 2850 ft. (Wilson 1930–31); the last is the most southerly occurrence in the British Isles.

In England it is known mostly from the Lake District, and also on several North Pennine summits of over 2000 ft., such as Mickle Fell, Great Shunner Fell, Ingleborough and Whernside (Wilson 1938; Cheetham & Sledge 1941). There is also a record for Snaefell, Isle of Man (Templeman 1924).

Widely spread in Ireland it is found on most summits over 2000 ft., from Sugar Loaf Mountain in the south-west and the Wicklow mountains in the east, to the heights of Donegal and Antrim in the north. Although descending to below 1000 ft. in Kerry it never reaches sea-level, as so many other highland plants do in Ireland (Praeger 1934).

In Scotland, *S. herbacea* occurs over a wide area in the highlands, including the Inner and Outer Hebrides, Orkneys and Shetlands. Here it is abundant on summits above 2100 to 2400 ft. and descends to 300 ft. in Sutherland (Marshall & Shoolbred 1909). In the lowlands, however, it is known only from Dumfries, Kirkcudbright and Ayrshire (an old record); its presence in Peebles is dubious, and it was seen just over the border in Northumberland in 1863 (Balfour 1902).

Fossil records of *S. herbacea*, mostly of the leaves, are relatively common; they are known from arctic beds of Hoxne (Suffolk) (Reid 1896) and Barnwell (Cam Valley) (Chandler 1921), and also from several localities in the Lea Valley; Barrowell Green (Warren *et al.* 1923*a*), Ponders End (Warren & Lewis 1912), and Angel Road and Temple Mills (Reid 1915). In Ireland it is recorded from several late-Glacial sites: Dunshaughlin, Co. Meath (Mitchell 1940), Ratoath, Co. Meath (Mitchell 1941), Drumurcher, Co. Monaghan (Mitchell 1942*b*) and Ralaghan, Co. Cavan and Ballybetagh (Jessen & Farrington 1938), all zone III and the last also from Zone II. S. *herbacea* has also been found in the Isle of Man (Ballaugh, Reid, 1897*a*; Kirkmichael, Lamplugh, 1903) in a late-Glacial deposit, and from various localities in Scotland, of which we may particularly note the occurrence at Whitrig Bog, Berwickshire (Mitchell 1948).

Salix sp.

Besides the numerous leaves of *S. herbacea* from the extreme base of the muds of site 42B there were various other remains such as wood, bark, bud-scales, as well as several leaves of a different form, which, although a specific identification was not possible, were apparently all *Salix*.

Wood of some 1 cm. diameter was collected towards the base of the mud at site 42B (at 290 cm.); sections showed the heterogeneous ray-cells characteristic of the genus *Salix*. In the upper part of the gravelly-soil deposit of site 42B and again in the upper layers of the lower peat (*Carex*-wood peat, site 42B) were smaller pieces of wood, also probably *Salix*, but differing somewhat from that at the base of the muds.

Associated with the latter material (i.e. *Carex*-wood peat of site 42B) and also of the lower part of the gravelly-soil were many bud-scales, which from their small size (*c.* 0·7 × 0·6 mm. and others *c.* 2·0 × 1·2 mm.), rounded shape, and the fact that they were formed from a single scale evidently also belong to some species of *Salix*. Similar bud-scales were also found in large numbers in the *Carex*-wood layers of the lower peat in site 36 (2 to 14 cm.).

These were associated with numerous twigs which had bark varying in colour from light grey to dark brown. In some cases the bud-scales were still attached to the twigs. All apparently were *Salix*, though which species it was not possible to say.

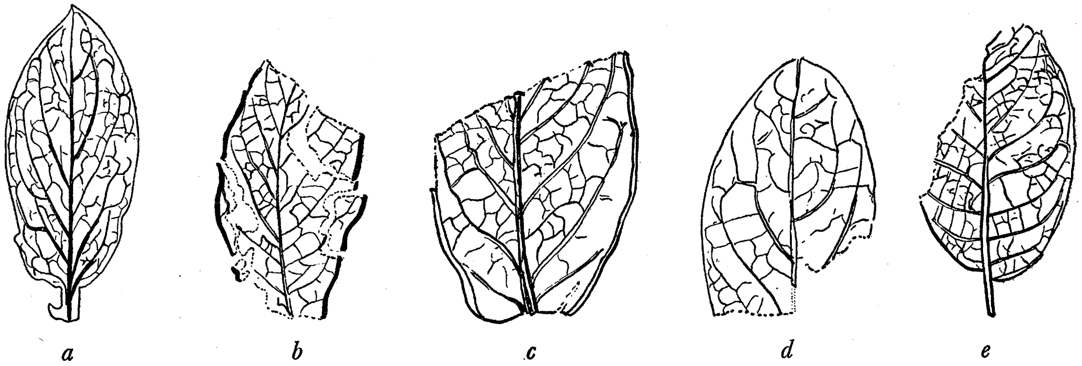

Figure 15. *Salix* sp. Leaves from Hawks Tor. *a* to *c*, site 42A, 100 to 98 cm.; *d*, *e*, site 36, wood layer of lower peat (not the peat monolith series). *a*, *c*, *d* (magn. × 6); *b*, *e* (magn. × 3).

Leaves (figures 7 and 15) of at least two species were collected from a woody layer at site 36 (not that of the peat monolith) and also from the extreme base of site 42A (100 to 98 cm.). These also probably belong to a small-leaved species of willow, but the fragments were not adequate for a certain identification, in view of the fact that the species that come within the size range, such as *S. repens* and *S. myrsinites*, are extremely variable in leaf form.

Saxifraga cf. *granulata* L.

Three seeds of a saxifrage from the lower layers of the lake mud at site 42B, 300 to 298, 298 to 296, 292 to 290, 280 to 270 cm., may be referred tentatively to *S. granulata*. From comparison with recent material available, two of the seeds agree with *S. granulata* in size and in tubercle pattern, which consists of numerous distinct small tubercles between regular rows of large ones (figure 9*i*). But it is possible that there are other species—for example, in the hypnoid or even the caespitose group—which have this character. The third specimen has crowded tubercles of only the small size; this might suggest *S. caespitosa*.

S. granulata L. is fairly widely distributed in this country but does not go north-west of Perth and Moray and does not ascend above 1500 ft. It is not known from Cornwall and is probably only introduced in Devon, although it occurs locally elsewhere in the south; in Ireland it occurs only round Dublin. In Europe it ranges south to central Spain, Sicily and Montenegro, and east to Poland, but north only to southern Norway.

S. hypnoides agg., on the other hand, has a distinctly northern distribution. In this country it is found widely in Wales and the border counties, Scotland and north England; it has its southern limit on the Pennines of Staffordshire and Derbyshire, with a single isolated station in Somerset. Elsewhere it is known from the Faröes, Iceland, Norway, Ardennes and Vosges.

S. caespitosa agg. is a species of arctic Europe, with a very restricted range in this country: Snowdonia and a few places in the highlands of Scotland, and various forms in Ireland.

S. hypnoides is known from late-Glacial deposits in Ireland (Jessen & Farrington 1938).

Sparganium angustifolium Michx.

Several nuts (figure 9*f*) agreeing with those of this species were found in most of the levels of the lower muds and peats and in the underlying gravel at site 36, and in muds of site 42B, 294 to 270 cm.

Some of the specimens were near *S. minimum*, but others somewhat larger (4·25 × 1·8 mm.) would seem to belong to *S. angustifolium* Michx. The distribution within the British Isles (figure 20, p. 438) of this species is similar to that for *Empetrum nigrum* but with a more pronounced restriction to the extreme west and north. The main area to the west lies in the coastal counties of Wales from Glamorgan and Carmarthen to Caernarvon, and in the north from Westmorland, Cumberland and Northumberland north through all Scotland. It is generally distributed through Ireland. South of these areas, in England, there are isolated localities from four counties: Surrey (Salmon 1931), Norfolk (Nicholson 1914), Staffordshire (Bagnall 1901) and north Lincolnshire (Woodruffe-Peacock (*c.* 1920) for record of 1898). For some at least of these, confirmation with herbarium material would seem desirable; the Surrey station, for example, has not been seen for 60 years.

This species has been recorded from the Lea Valley at Barrowell Green (Warren *et al.* 1923*a*).

Sparganium minimum (Hartm.) Fr.

Besides the stones of *S. angustifolium*, there were a few from site 42B, 294 to 292 cm., which were smaller than the others; they measured about 1·75 mm. in length, and are referred to *S. minimum*.

Sparganium erectum L. or *S. neglectum* Beeby

From the upper mud of site 42B, 280 to 262 cm., and rarely elsewhere, there were many rather irregular stones often with the remains of a thick, rather soft, fibrous covering. They vary much in form, especially in breadth, but almost all show eight longitudinal ridges which increase in size towards the apex and there end abruptly. The narrower ones compare favourably with fruits of *S. erectum* from which all the soft parts have been dissolved away; the wider ones seem nearer to *S. neglectum*.

Subularia aquatica L. (figure 16)

Several seeds from the lowest lake muds of site 42B, 300 to 290 cm., and the gravel just beneath, correspond closely in shape, size and superficial marking with those of modern specimens of *S. aquatica* L.

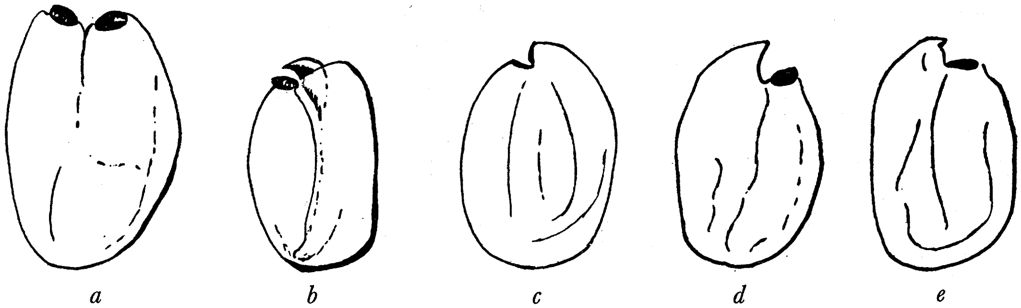

FIGURE 16. *Subularia aquatica* L. Seeds: *a*–*d*, Hawks Tor, site 42B, 298 to 296 cm.; *e*, from Herbarium material (magn. × 30).

This species to-day extends through north and east Europe including the extreme north of Finland, Iceland and the Faröes; Greenland; Siberia and North America.

In Britain (figure 19) it occurs as a highland plant of Wales and north Britain where localities are not numerous; the majority are from mountain tarns and small lakes, where it grows in shallow water often in company with *Lobelia dortmanna* L.

In Wales, stations for *Subularia* are confined to the west, extending from Llyn-y-fan-fach in Carmarthenshire (Riddelsdell 1904) to Llyn Llywenan in Anglesey (Griffith 1895); the majority are from the lakes of Snowdonia.

English records all lie within the Lake District region, with an isolated occurrence west of Carlisle (Butcher 1937). It is evidently not now known for the Isle of Man (Trail 1898; Paton 1933, 1944).

Records from Ireland are now restricted to the west coast between Gouganebarra in west Cork and Mueelrea in west Mayo. Former records, except for a doubtful station in Donegal, all occurred around Lough Neagh and its entry and exit; that from Lough Beg alone existed in 1888, but the plant has not been seen here subsequently (Stewart & Corry 1938).

In Scotland, *Subularia* has its widest distribution in Britain. Here, apart from the eastern lowlands, there are records for most vice-counties, including the Shetlands but not the Orkneys.

There are no available data on past distribution.

Thalictrum alpinum L. (figure 9*a*)

A single achene closely resembling this species was found from site 42B, 296 to 294 cm., in the base of the muds.

This species is included in Matthews's arctic-alpine element (Matthews 1937), and only just fails to come within Polunin's definition of a truly arctic plant (Polunin 1939). It is mentioned by Dahl (1946) as a survivor of the last glaciation on the coastal mountain refuges of Scotland, Iceland, southern Greenland, and west and north-west Scandinavia.

To-day *T. alpinum* is distributed in arctic and sub-arctic Europe generally, where it extends north to 72° to 74° N. in Nova Zemlya; in the mountains of central Europe, and the Pyrenees; Asia and North America, including Greenland and Alaska.

In the British Isles (figure 19) it is confined to mountain localities of over 2000 ft., and is common only in the highlands of Scotland.

In Wales it is restricted to Snowdonia, and in England to the Lake District and to Upper Teesdale (and immediate vicinity).

In Ireland it only occurs in the extreme west from Kerry at 3000 ft., where it has not been seen for 60 years, and from Galway to Donegal. Always local, on high mountains, it never descends to sea-level as so many highland plants do in this part (Praeger 1934).

Rare in south Scotland (only Dumfries, and Kirkcudbright with some uncertainty) it occurs in Dumbarton, Stirling, Perth and to the north generally, except the extreme east (i.e. Fife, Kincardine, north Aberdeen and Moray), and the southernmost Inner Hebrides. It ascends to nearly 4000 ft. and descends to lowland levels only in the Shetlands, and to near sea-level at the extreme north of the Scottish coast (Marshall, 1901).

T. alpinum has been recorded from the Barnwell Beds, Cambridge (Chandler 1921), and from the late-Glacial deposits in the Lea Valley (Reid 1915). In Ireland it has been reported from zone II of the late-Glacial at Ballybetagh (Jessen & Farrington 1938) and from zone III at Drumurcher (Mitchell 1942*b*). In Scotland it has been found in late-Glacial clay at Whitrig Bog, Berwickshire (Mitchell 1948).

Attention is drawn to the fact that pollen of the genus *Thalictrum* was found throughout the lower organic layers at site 36, 0 to 31 cm., and through both the lower organic layers and the overlying gravelly-soil at site 42A, 98 to 10 cm.

Veronica anagallis-aquatica L.

Small seeds of *Veronica* were abundant in the upper muds and detritus layers of site 42B (figure 9*g*). Besides their characteristic shape the size range (up to 0·6 mm. in length) limits the identification to *V. anagallis-aquatica* L., *V. aquatica* Bernh. and *V. beccabunga* L. Of these, the last has a seed a little longer than the average specimens from Hawks Tor and a little less near in shape than have the other two species. Whether one can distinguish *V. anagallis-aquatica* from *V. aquatica* on seed characters alone is doubtful, so that either of these two species may be represented at Hawks Tor.

There were, besides, certain somewhat larger specimens which may belong to *V. beccabunga* L.; and at site 42B, 280 to 262 cm., there were other *Veronica* seeds considerably larger (1·3 × 1·2 mm.) and nearly circular in outline; these were rather similar to the seed membranes of *V. scutellata* L., but had not sufficient features to be accurately identified.

Viola cf. *palustris* L.

As all *Viola* seeds are very similar one cannot be certain that the specimens are of *V. palustris*, but they compared closely.

The list of species in tables 1 to 3 includes some fifty flowering plants, and their phytogeographical status is of interest.

Six of the species may be termed 'arctic' in that they either come within Polunin's definition of a truly arctic species (extending north of the 75° N. (Polunin 1939); or else they belong to Matthews's 'arctic-alpine' element (Matthews 1937). These are:

Betula nana	*Caltha palustris*
Salix herbacea	*Eriophorum angustifolium*
Thalictrum alpinum	*Hippuris vulgaris*

Of these, the first three listed are to-day restricted in the British Isles to northern localities, and only occur farther south, if at all, on the higher mountains, or in Ireland on the extreme west coast (see figure 19). These three are also all species of relatively dry terrestrial habitats, and in the Hawks Tor deposits were recovered only from the extreme top of the lower peat or from the basal muds (*Betula nana* fruits were rare also in the upper part of these muds). The other three species in this group are either aquatics or plants of wet habitats; they have a much greater range in this country, all but *Hippuris* being known throughout Britain, including Cornwall, and in the Hawks Tor deposits they were not significantly restricted to any particular level.

A further ten species may also be ranked as 'northern', though not markedly arctic; they mostly are included in Matthews's 'northern-montane' or 'continental-northern' elements (Matthews 1937). Seven of these show a northerly distribution within the British Isles and do not to-day occur in Cornwall:

Subularia aquatica	*Montia 'lamprosperma'*
Callitriche autumnalis	*Rumex acetosella* L. (s.s.)
Empetrum nigrum	*Saxifraga hypnoides*
Sparganium angustifolium	

Subularia and *Callitriche autumnalis* are representative of the more sparsely distributed species (local even in Scotland), with a north-western distribution (figures 19, 20), *Empetrum* and *Sparganium angustifolium* representative of those fairly widespread in the north and west and extremely local and dying out in the south-east (figure 20). Five of these seven species were again found in the Hawks Tor sites only in the basal muds or in the extreme top of the lower peat. The three remaining species of this group are all marsh aquatics and occur throughout Britain including Cornwall: these are, *Comarum palustre*, *Viola palustris* and *Menyanthes trifoliata*.

Another group of species includes those which, in contrast, do not occur in the extreme north of this country, nor extend to the Arctic Circle (as do all those of the two former groups, *Empetrum* to 63° N.). Here we have:

Saxifraga granulata	*Erica tetralix*
Veronica aquatica	*Carduus nutans* or *crispus*
Lycopus europaeus	*Potamogeton densus*

Potamogeton crispus only reaches north to 69° N. (in Norway). In the Hawks Tor deposits these were mainly found in the detritus mud or the *Carex-Hypnum* and *Carex*-wood peat except for the *Erica* from the base of site 42A.

The remaining species on the list that have been identified with some certainty (tables 1 to 3) all reach the Arctic Circle in Europe, and all but *Potamogeton alpinus* and *Juniperus communis* are known from Cornwall to-day. The only plants of dry habitats are: *Leontodon autumnalis*, *Sorbus aucuparia* and *Rumex acetosa*, species of wide distribution extending far northwards.

Thus those species with the strongest arctic character are from the lowermost layers (gravel surface and lower muds) and from the uppermost surface of the lower peat. There is also a tendency for those species which are the least northern in range to be in the middle and upper layers of the lower peat.

(*b*) *Bryophyta*

Antitrichia curtipendula Brid.

Several leaves of *A. curtipendula* Brid. were recorded from the uppermost muds of site 42B (270 to 262 cm.), but none from the lower layers. This species is widely though sparsely spread through Britain to-day, extending from east Cornwall and Kent to Caithness. It forms a constituent of a moss society that occurs both on rocks and on trees in subalpine/alpine and subarctic/arctic regions, in the alpine zones becoming exclusive to rocks (Gams 1932*a*) but in lowland places and in Britain it is more common on trees (Richards 1932), as, for instance, in Wistman's Wood, Devon, where it clothes old oaks (Dixon 1924); but it is also found on rocks in the more mountainous parts of Britain. In Scandinavia it is considered as hardly extending beyond the forest belt (Jensen 1939), and Degelius (1935) lists

A. curtipendula among his western (suboceanic) species of mosses, which in Scandinavia are much more frequent in the west although the general distribution is preponderantly southern or ubiquitous. Beyond Europe this species also occurs in Madeira, Canaries, Abyssinia, South Africa, Patagonia and North America (Mönkemeyer 1927).

Gams (1932*b*) mentions this species as one whose remains are particularly frequent from the warm post-Glacial period, when such southern and oceanic species reached higher latitudes and altitudes. Moreover, Mitten (Reid 1897*b*), commenting on an assemblage of mosses including *Antitrichia* from a fresh-water inter-Glacial deposit at Hitchin with an unmistakable temperate flora, points out that 'all these are inhabitants of a sylvan temperate region...they are not arctic'. This species has also been recorded from a Scottish post-Glacial deposit (Dixon 1910), where it formed the bulk of the material in an assemblage that suggested a climate at least not appreciably colder than now prevailing, though there was included a little *Blindia*.

Blindia acuta B. & S.

These specimens, which consisted of several short leafy shoots, all came from the lowermost muds of site 42B. They compare fairly closely with *B. acuta* B. & S., but differ from the usual form of that species in the much shorter areolation which tends also to be somewhat irregular. They also differ in the quite entire, very acute, apex (figure 17) and in the abruptness with which the leaf narrows into the subula. All these are features shown by the rare *B. caespiticia* Lindb., which is known in Britain only from Ben Lawers (Perth), but without fruit one cannot be certain about this species. Moreover, *B. acuta* is itself a variable species, and examination of fruiting material from above Gletsch, Switzerland, shows that, at least in some leaves, all these features may be developed. It would seem unnecessary then to seek further than *B. acuta* for the identification of the Hawks Tor material, though it is at least possible that it is an alpine form that is represented.

FIGURE 17. *Blindia acuta* B. & S. Leaf apices, Hawks Tor, site 42B, 292 to 290 cm. (magn. × 600).

B. acuta grows characteristically on bare wet rock faces in alpine and subalpine places most frequently over 1500 ft. (Watson, W. 1925). It mainly occurs in Britain in the north and the west (figure 21). It has once been recorded from west Cornwall (Rilstone 1948; record of 1896), and also from Devonshire. It is known in Wales for the majority of counties, and from the border counties of Monmouth, Hereford and Shropshire. To the north, it is of rare occurrence in Derbyshire (The Peak) and on the Pennines of west Lancashire and west Yorkshire. But it is frequent in Westmorland, and from north Yorkshire northwards it is known from the rest of England and throughout Scotland. It is recorded also from the Isle of Man, and in Ireland from most of the counties in which mountain ranges occur.

It is of interest that Gams (1932*b*) mentions *B. acuta* as known from post-Glacial deposits from Scotland (Dixon 1910), but not, although suspected of being overlooked, as hitherto recorded from older deposits.

Climacium dendroides Web. & Mohr.

Leaves of *C. dendroides* occurred with those of the *Antitrichia* in the uppermost muds of site 42B (270 to 262 cm.) but not at lower levels.

This species is of much wider distribution than *Antitrichia* and is not, as that species, restricted to Oceanic regions; nor does it extend into the high mountain regions. It is, indeed, widespread throughout the holarctic region (Gams, 1932*a*) and is certainly by no means to be regarded as either an arctic or an alpine.

Climacium is a species of wet meadows, growing amongst grass and in swampy places and on the less acid moors amongst *Carex*, *Eriophorum*, etc., but it can also grow on sand-dunes.

Climacium dendroides has been recorded from the type locality of the Allerød, in the lake-mud of zone II (Hartz & Milthers 1901), and in the inter-Glacial beds at Wolvercote (Bell 1904).

Dicranum sp.

Among the leaves of *Antitrichia* and *Climacium* from the uppermost muds of site 42B (270 to 262 cm.) were several leaves and an occasional apical bud of a moss that resembles a *Dicranum*.

The cells both basally and towards the upper part of the leaf were thick-walled and porose; elongate below, shorter, sinuose or rhomboidal above, smooth. The leaves were short, none more than 2 cm. long, erect, never falcate, folded or in some cases inrolled, and not contracted into a narrow subula. The rather wide apex was quite entire without any serration, either of the margin or on the back of the nerve.

On these cell characters the only British species to be considered are *D. scoparium* and *D. bonjeani* (*D. majus* has always much longer, serrate leaves, and *D. molle* is longly subulate). But the Hawks Tor specimens do not resemble either typical *D. scoparium* or *D. bonjeani*. For the latter typically has undulate usually flat leaves, and *D. scoparium* narrow ones with a long fine subula; in both the leaves are much longer and both are normally serrate—at least apically—and in *D. scoparium* on the nerve dorsally as well.

However, both these species are extremely variable, and in each case forms have been described (Jensen 1939; Mönkemeyer 1927) with entire leaves, including for *D. bonjeani* some which are not undulate. The var. *spadiceum* Zett. of *D. scoparium* has inrolled sometimes entire leaves but is normally longly subulate. It would seem then that we may have a small form of either *D. scoparium* or *D. bonjeani*, but one cannot rule out the possibility of some other species.

Both these are common and widespread species which occur throughout the British Isles.

Plagiochila asplenioides (L.) Dum.

A single leafy branch of this species came from the *Carex-Hypnum* peat of site 36 *I*. This species is very common on the loose humus on the surface of shaded rocks, on tree-stems in moderately humid situations and on banks with a fair vegetation cover, although it can extend into the moss association of mountain tops (Watson, W. 1925). It is of widespread occurrence throughout Britain and Europe, and the whole holarctic zone; in Scandinavia it is regarded as of southern distribution (Degelius 1935). Gams (1932*b*) mentions it as occurring in the warm inter-Glacial period.

Polytrichum alpinum Hedw. cf. var. *septentrionale* Brid.

Several fragments of leafy stems, and many separate leaves of a *Polytrichum* were found at the extreme base of the muds and in the underlying gravel at site 42B. No fragments of the plants were more than 1 cm. long. The leaves were rather crowded and falcate to patent; in size and form they varied from more or less straight with margins spinous throughout to subsecund with nearly, or completely entire, incurved margins. The lamina was in no case more than 3 to 4 mm. long and the sheath at most 1·5 mm.; the basal cells were elongate, never quadrate. The lamellae were 6 to 10 or more cells high, with straight thickened papillose margins; the border cells were mostly taller than broad in lateral view, and in section roundish with a heavily thickened conical apex, the latter somewhat, but not heavily, papillose (figure 18*a*, *c*, *d*).

Of the European species of *Polytrichum* only *P. urnigerum* and *P. alpinum* have thickened papillose border cells to the lamellae. *P. urnigerum* Hedw., including the subspecies *capillare* Mich., has been distinguished by the border cells being broader than high (Albrecht 1934). Further, in this species, these border cells are round (truncate in *capillare*) without the conical apex shown in the Hawks Tor material, and are heavily papillose all over. On these characters the Hawks Tor *Polytrichum* is clearly not *P. urnigerum*. The other species in this group, *P. alpinum*, is typically a large plant with stems up to 20 cm. and correspondingly long leaves normally serrate throughout. The lamella (6 to 8 cells high) has the border cells usually much taller than broad in lateral view, and in section they are ovate-conical with a conspicuous conical apex. This corresponds with the Hawks Tor specimens, although typically in *P. alpinum* the border cells are much more papillate (figure 18*g*, *h*). *P. alpinum* is, however, extremely variable, and our plant must, from these characters, belong here. Two extreme forms have been described as var. *arcticum* Wahl. (=var. *sylvaticum* Lindb.) and var. *septentrionale* Brid. (Albrecht 1934). The former has tall stems, long flexuous leaves with long sheaths and a lamina of 6 mm.; var. *septentrionale* has short (up to 3 cm.) densely tufted stems, short leaves with a lamina of only 4 mm., somewhat secund, the margins subentire to entire, somewhat inflexed, the lamella papillosity sometimes faint.

On these characters the Hawks Tor material agrees more closely with the var. *septentrionale* than with either the type or var. *arcticum*. Comparison with Swedish herbarium material on the whole substantiates this; the lateral views of the lamellae are especially alike (figure 18*a*, *b*), but in section the lamella border cells of the Hawks Tor material, although agreeing with *P. septentrionale* (figure 18*e*, *f*) in the faint papillosity, are for the most part but not in all cases somewhat broader. In this they resemble the var. *arcticum* (figure 18*i*, *j*), but here, as in *P. alpinum* s.s. (figure 18*g*, *h*), the papillosity is very much denser; moreover, the height of the lamellae in *arcticum* would, from the material available, seem not to exceed 5 or so cells, whereas in *septentrionale* they are commonly 6 or 7 high and in the Hawks Tor material 7 to 10. It would thus seem that we have undoubtedly a form of *P. alpinum* and possibly one near to the var. *septentrionale*.

P. alpinum var. *arcticum* is an alpine not known from the British Isles. The var. *septen-*

trionale is a rather extreme high-altitude form, ascending to 500 to 1000 m. in Scandinavia (Albrecht 1934). It has only been recorded in the British Isles from Ireland: from Slieve League, Co. Donegal; Kerry; west Mayo; and from Louth; and also from one of the higher Scottish mountains (Aonoch Moor, Inverness). It has not been recorded from England.

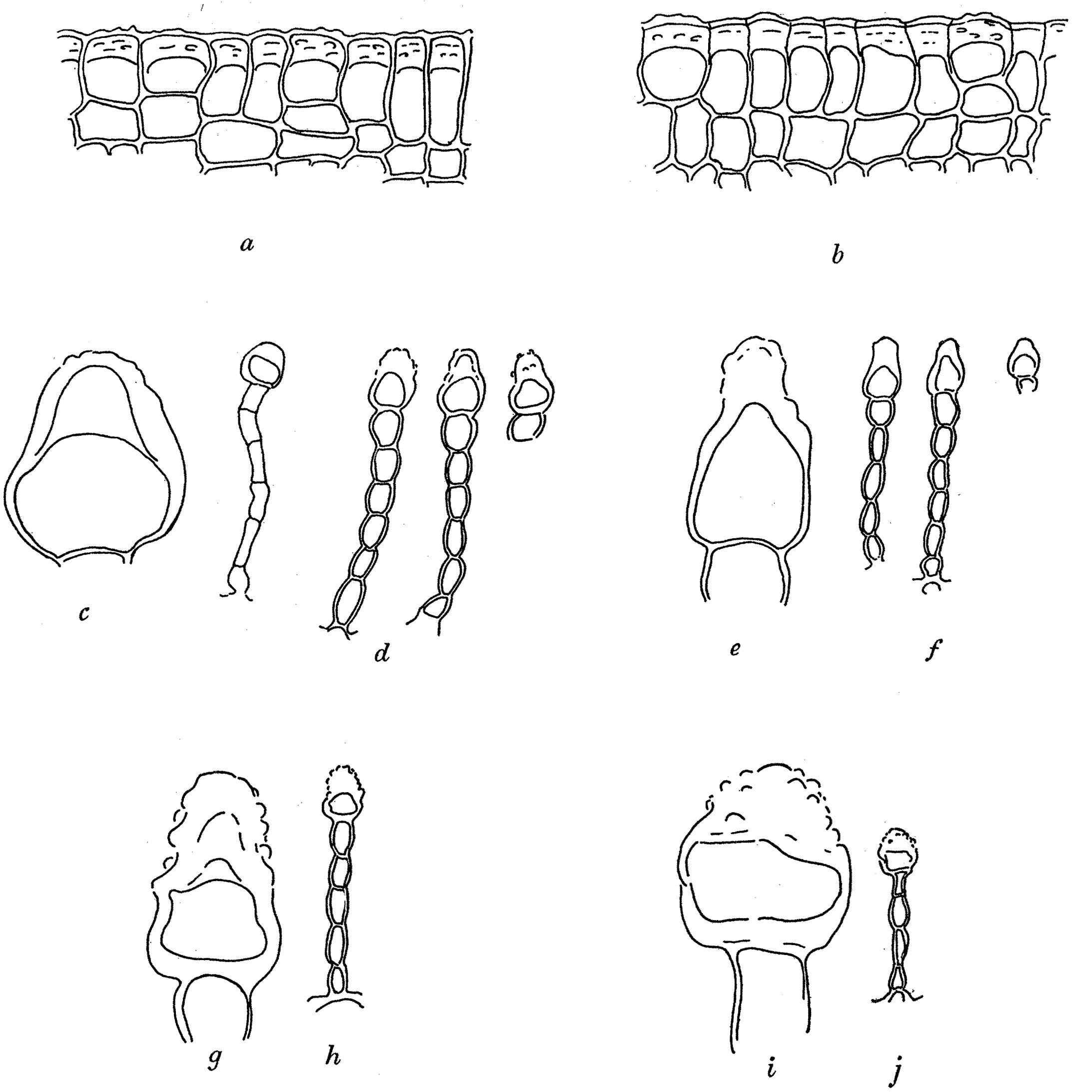

FIGURE 18. *Polytrichum alpinum* L. cf. var. *septentrionale* Brid. *a*, lateral view of lamella; *c*, end-cell of lamella section; *d*, lamellae sections. Hawks Tor, site 42B, 300 to 298 cm. *Polytrichum alpinum* var. *septentrionale* Brid. from Scandinavian herbarium material. *b*, lateral view of lamella; *e*, end-cell of lamella section; *f*, lamellae sections. *Polytrichum alpinum* L. from British herbarium material, Westmorland. *g*, end-cell of lamella; *h*, lamella section. *P. alpinum* cf. var. *arcticum* Wahl. from herbarium material. *i*, end-cell of lamella; *j*, lamella section. *a*, *b* (magn. × 600); *c*, *e*, *g*, *i* (magn. × 1200); *d*, *f*, *h*, *j* (magn. × 300).

P. alpinum itself, although also considered as an arctic-alpine (Watson, W. 1925), is more widespread, though only occurring in the north and west of Britain, its distribution being generally comparable with that of *Blindia acuta* (figure 21). *Polytrichum alpinum* is abundant in the moss-lichen association of mountain-tops, also occurring in the snow-patch vegetation in association with *Salix herbacea*, and in shady crevices. It occurs throughout Scotland and the north of England and south to Derbyshire; in the west it is known in Wales and the

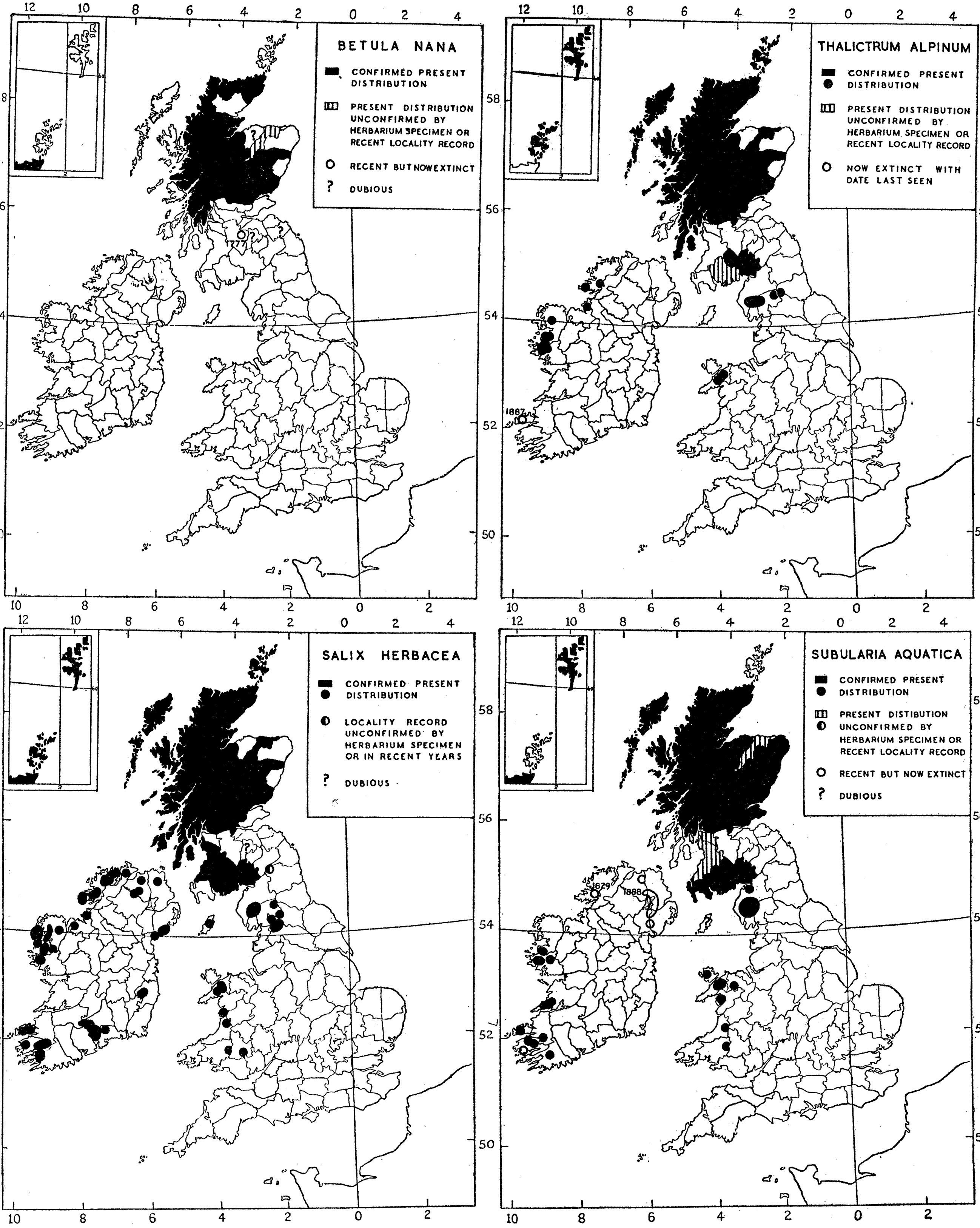

FIGURE 19. Present and recent distribution in the British Isles of species found in the lower peat at Hawks Tor, Cornwall.

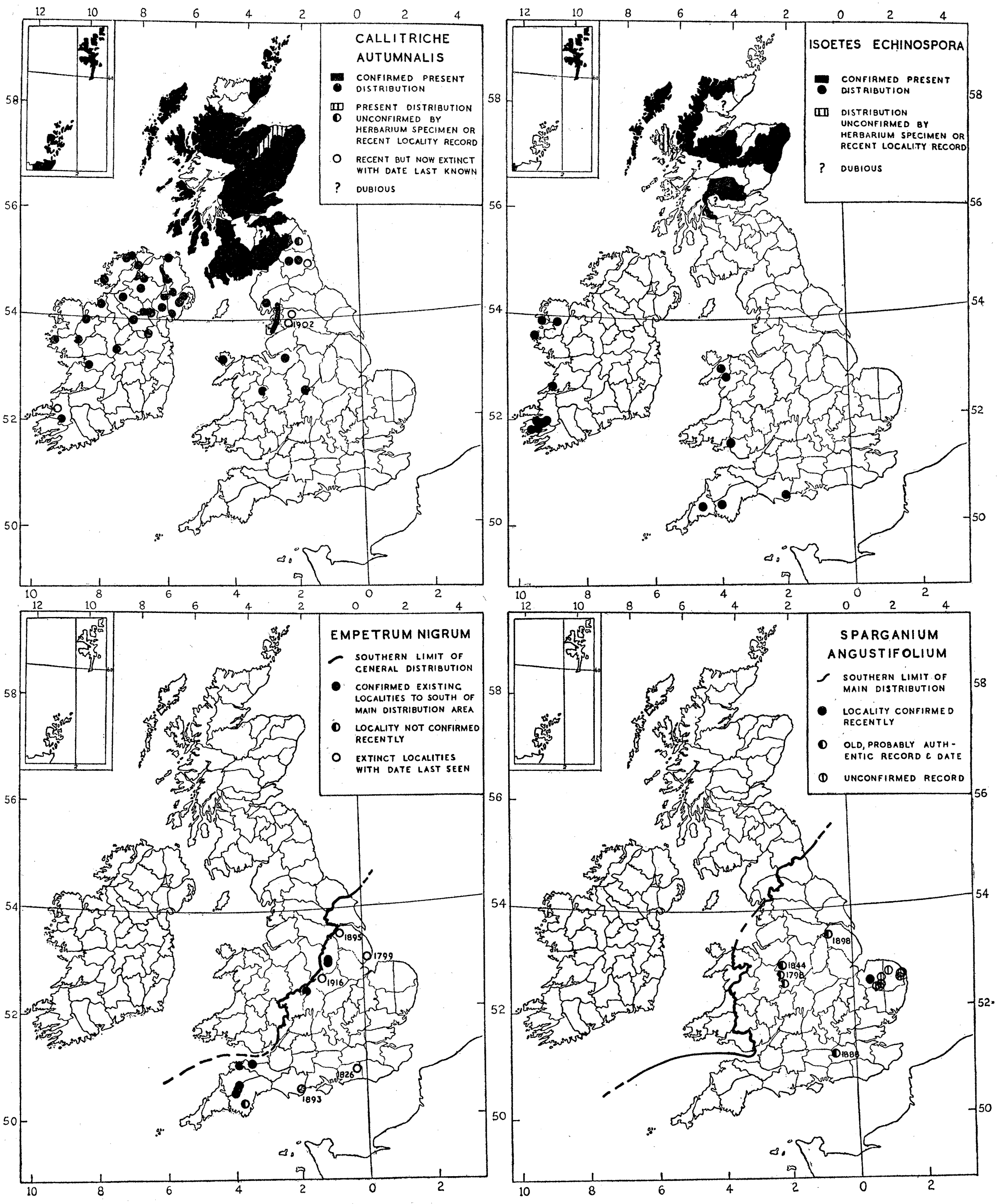

FIGURE 20. Present and recent distribution in the British Isles of species found in the lower peat at Hawks Tor, Cornwall.

Border counties including Worcester and Gloucester; and in the south-west from Devon and Cornwall.

P. alpinum has been recorded from late-Glacial deposits of zone II from the bottom deposits of Windermere (Pennington 1947).

From the list of bryophytes identified there are five or six species which may be considered characteristic of moderately dry terrestrial communities, and which on this acccunt may be better climatic indicators than aquatic species.

Of these, two species were found only in the extreme base of the deposits and both of these, *P. alpinum* and *Blindia acuta*, are species with a northern distribution and considered to be of alpine or arctic-alpine affinity; both are restricted in Britain to-day to the extreme west and to the north, where alone they are common. There is a possibility in both cases too that we have either a variety, or a closely related species with an extreme northern distribution, and which only occurs in Britain in a single highland locality. They are either species of bare rock (*Blindia*), or often of open stony ground on mountain tops (*Polytrichum alpinum*), though the latter occasionally occurs in more grassy places.

The three other species of terrestrial habitats were, in contrast, only found from the uppermost muds—that is, towards the middle of the lower peat. These species, *Climacium dendroides*, *Antitrichia curtipendula* and *Plagiochila asplenioides*, are all much more widespread species than are *Polytrichum alpinum* or *Blindia*, and although reaching the Arctic Circle (in Scandinavia) they cannot be said to be of northern distribution. In fact, *Antitrichia* may be

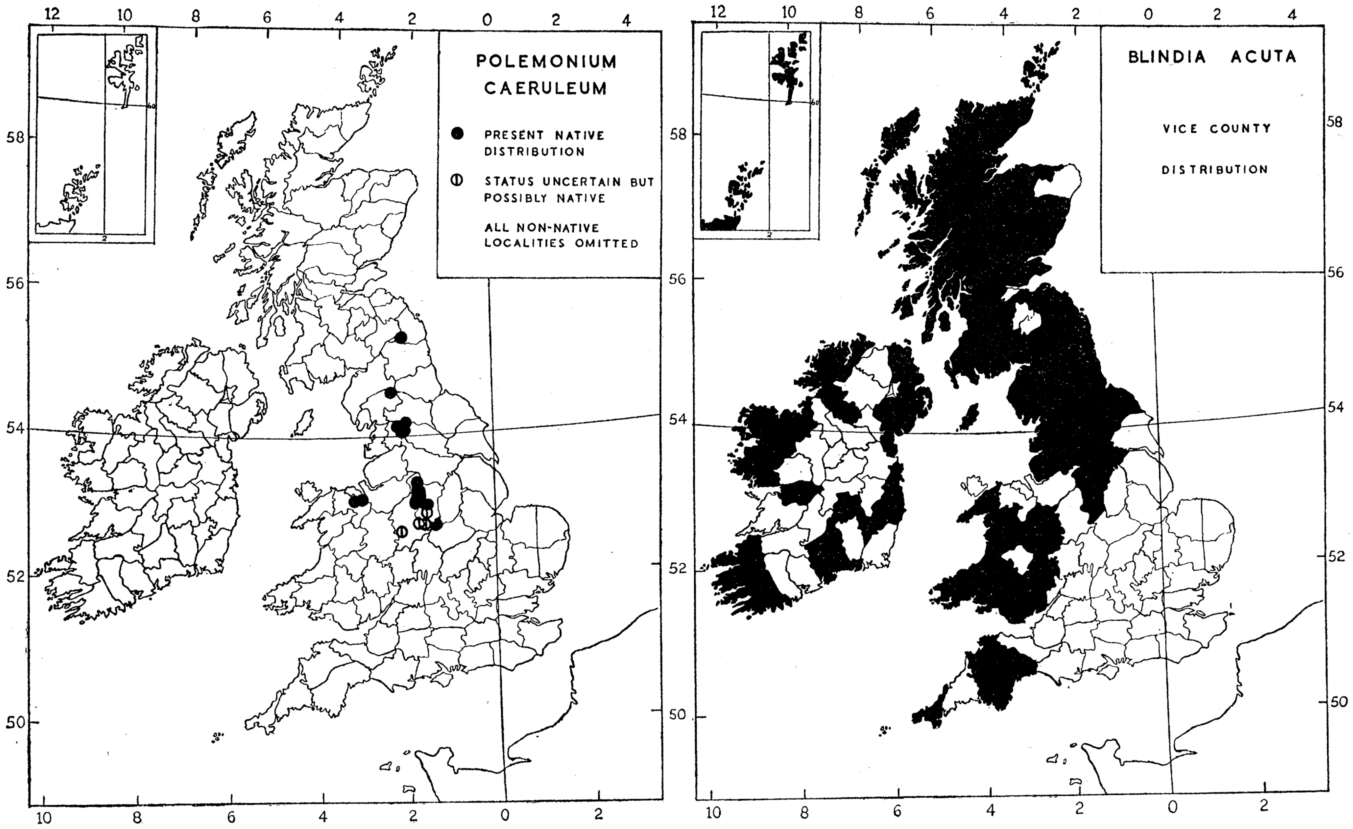

FIGURE 21. Present and recent distribution in the British Isles of species found in the lower peat at Hawks Tor, Cornwall.

regarded as a western (oceanic) species, *Plagiochila asplenioides* even as of southern affinity, and *Climacium dendroides* as ubiquitous. They also either favour a more closed vegetation community or the humus cover of rocks or trees. Thus, although these species have all been recorded—if rarely—in Cornwall within recent times, some indication at least is given by their general distribution and habitat of more temperate conditions replacing the more extreme alpine-arctic aspect represented by the species in the basal layers, and also of deeper-soil communities replacing those of shallow or open soil and bare rock.

A sixth species, *Mnium affine* Bland., is a plant of damp ground in woods, but with varieties growing in bogs and marshes. This specimen occurred in the muds of the lower peat in a position intermediate to that of the previous groups (site 42B, 280 to 290 cm.).

Apart from these five or six terrestrial species all the other bryophyte species identified with certainty are characteristic of aquatic or very wet habitats and are thus less indicative of climatic conditions. They are all species widespread in Britain to-day.

The bulk of the moss forming the *Carex-Hypnum* peat layer of the lower peat was *Hypnum revolvens* Swartz. This species has been frequently found in Quaternary deposits from most periods (Gams 1932*b*).

5. POLLEN-ANALYSES

(*a*) *Post-Glacial sequences in neighbouring sites*

Since published series for comparison are lacking in the south-western peninsula, our investigations have been extended to embrace pollen diagrams from three neighbouring sites on Bodmin Moor, but none of these has been considered with the closeness of the Hawks Tor investigation. All the same they jointly establish an outline of the post-Glacial history of the region which permits correlation with the sequence in Ireland and in other parts of southern England and Wales. Since Jessen has now adopted for Ireland the same zonation as that proposed for England and Wales (Godwin 1940*b*), this correlation is simplified.

(i) *Parsons Park* (figure 22)

This site lies 3¾ miles (6 km.) south-east from Hawks Tor and at about 2 miles north-north-east of the village of St Neot. The china-clay pit is situated on a slight rise known as Parsons Park between the two uppermost branches of a small stream which rises on the southern slopes of Brown Gelly (1112 ft.) and flows southwards to join the Fowey river. As at Hawks Tor, this site is on the 750 ft. contour, but the natural vegetation of what must formerly have been a moorland marsh has been modified through the activities of upland farming and the china-clay working, leaving a surface vegetation of rough grass overlying a peat bed drained by the excavation of the pit. No good section was obtained, but the stratigraphy of the best preserved portion, where the samples were taken, was as follows:

cm.	
0 to 60	Moderately humified peat containing many roots of *Eriophorum vaginatum* and *Molinia* (H 2–3). A sharp contact at the base with black ash and charcoal.
60 to 100	Black highly humified peat containing *Eriophorum vaginatum* and *Molinia* rootlets (H 7–8).
100 to 119	*Phragmites* gyttja (organic nekron mud).
119 to 126	Light grey clay gyttja.
126 to 134	Gyttja containing wood fragments.
134 to 152	*Phragmites* gyttja with wood fragments.
152 to 213	Gyttja and amorphous peat. Much wood at 175 cm.
213	Granite gravel overlying the kaolinized deposits.

This section, which was about 30 yd. from the edge of the basin, appeared typical of the deposits in this pit, where (at least in the section then exposed) there was no real 'lower peat' as at Hawks Tor.

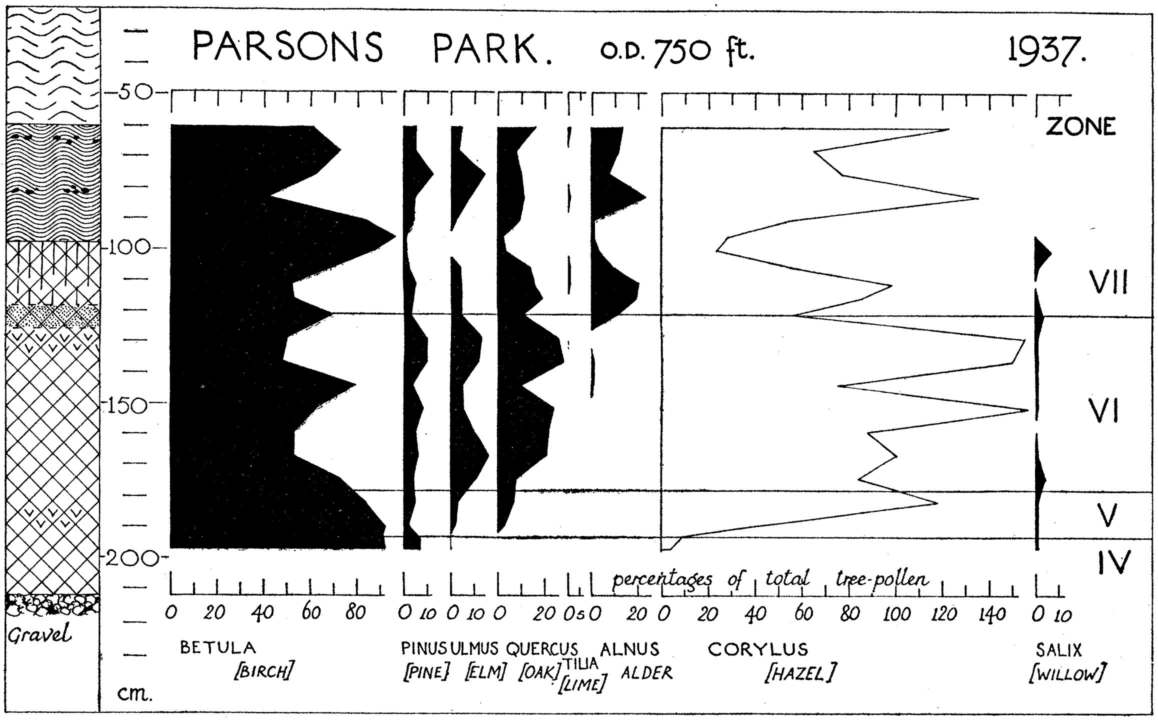

FIGURE 22. Pollen diagram: Parsons Park, Bodmin Moor, Cornwall.

The boundary between zones VI and VII can be confidently set at 121 cm. where the *Alnus* curve makes its definite rise, and beneath which no *Tilia* is present; it corresponds with the top of the clay-mud layer. The later strong depression of the *Alnus* curve may without doubt be attributed to very pronounced local preponderance of *Betula* woods which, it will be noted, affects all the other pollen curves between 90 and 105 cm. at an horizon where the peat stratigraphy also indicates sudden local vegetational change. The base of zone VI is taken to be at 180 cm. where the *Ulmus* and *Quercus* curves first rise to the characteristic high values of zone VI*a*. At 193 cm. we have set the boundary between zones V and IV, partly on account of the absence of elm and oak, and partly on account of the rapid rise of the hazel curve begun at this level. It is not, however, certain that local preponderance of birch woods could not be the cause of these effects.

It will be noted that between the surface of the gravel and the lowest analyzed sample in the diagram there is 14 cm. thickness of organic mud. Slides made up from two samples (213 and 210 cm.) in this layer were discounted as unanalyzable in 1937, but on re-examination in 1948 they yielded the pollen count shown in table 4.

These results, although based upon fewer total tree pollen than those higher in the series, are nevertheless of considerable value. In both, apart from a single much-weathered grain of *Alnus*, the tree pollen consists only of *Betula* and *Pinus*, the former greatly preponderating, and *Corylus* is present in small percentage only. This conforms to the view that these muds, directly over the gravel, are at least as old as zone IV. Strength is given to this view by the abundant non-tree pollen, which in the lower of the two samples includes, besides pollen of the aquatic *Myriophyllum alterniflorum*, grains of *Thalictrum*, *Armeria* and *Artemisia*, all genera indicative of open habitats and becoming widely recognized as jointly characteristic of late-Glacial plant communities. In the lower sample also, pollen of sedges and grasses is abundant relatively to tree pollen, although exact counts are impossible. The upper of the two samples though lacking the three most characteristic genera mentioned above, nevertheless contains pollen of *Empetrum*, *Valeriana* and *Scabiosa*, which in other late-Glacial or early post-Glacial sites accompany them.

TABLE 4. PARSONS PARK

	213 cm.	210 cm.
Betula	+	94
Pinus	+	6
Corylus	+	10
Gramineae	+	10
Cyperaceae	+	+
Armeria	+	—
Artemisia	+	—
Compositae	—	14
Empetrum	—	42
Ericoid pollen	—	6
Myriophyllum alterniflorum	+	—
Ranunculus	—	2
Scabiosa	—	2
Thalictrum	+	—
Umbelliferae	—	4
Valeriana	—	2
Sphagnum and other moss spores	—	658
Fern spores	—	10

(The count of sample 210 cm. is based on fifty-tree pollen.)

(ii) *Dozemare Pool* (figure 23)

This famous pool, long associated with Cornish legend, lies 3 miles (4·8 km.) due east of Hawks Tor. Samples were collected (1936) and analyzed by Mrs Megaw. Stratigraphy is as follows:

cm.	
0 to 72	Unhumified fresh peat.
72 to 95	*Sphagnum-Eriophorum* peat with lake-mud at the base.
95 to 185	Moderately humified *Sphagnum-Calluna* peat with thin layers of ash and charcoal at 147 and 154 cm.
185 to 207	*Sphagnum-Eriophorum* and some organic mud.
207 to 230	Brown and black organic lake-muds (nekron mud).
230 to 260	White nekron mud.
260 to 270	Dark brown nekron mud with *Phragmites* at 260 cm.

Pollen was too sparse to count above 90 cm. and below 230 cm. The boundary between zones VI and VII falls at 190 cm., whilst the top of zone V is about 215 cm. There is fair likelihood that the top 1 m. of peat formed in zone VIII, and there is ample depth of organic mud beneath the lowest counted sample to record the history of zones IV and V. It is clear that this site might well repay closer study by the more effective techniques now available.

Apropos of Iversen's findings upon the influence of forest clearance by prehistoric man, we may note that the layers of ash and charcoal in this diagram correspond here as in

Denmark with sharp temporary disturbances in the run of tree-pollen curves. Detail is insufficient, however, to warrant the analysis of these disturbances in vegetational terms.

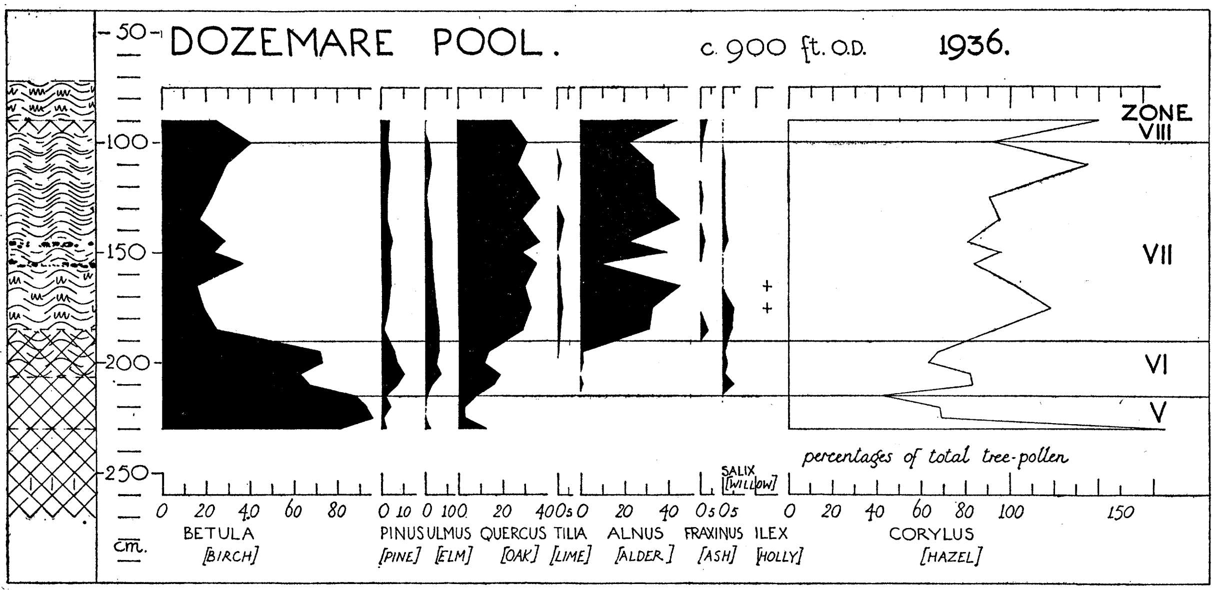

FIGURE 23. Pollen diagram: Dozemare Pool, Bodmin Moor, Cornwall.

(iii) *Stannon china-clay pit* (figure 24)

Samples were taken from the north-east end of the clay pit at Stannon Marsh, which lies 4¼ miles (6·8 km.), north-north-east of the Hawks Tor site and at an altitude of 750 ft. O.D. Although the samples were collected by Mrs Megaw, the greater part of the pollen counting was done by Mrs Hazel Whitmore.

Some checking and extension of counting was made by Miss R Andrew in 1948.

Stratigraphy shows the following sequence:

cm.	
0 to 40	Fresh *Molinia* peat with roots of *Eriophorum vaginatum*.
40 to 103	Grey detritus mud with very abundant diatoms in upper layers, and some coarse sand or fine gravel throughout. At 70 cm. charcoal; at 95 to 100 cm. *Phragmites*.
103 to 128	Sandy clay.
128 to 142	Nekron mud (gyttja).
142	Granite gravel.

It seems probable that the fresh upper peat formed in zone VIII, a suggestion borne out by the occurrence of pollen of *Fagus* and *Carpinus*. Zone VII extends between 45 and 88 cm., at which latter level there is the characteristic large rise of *Alnus* pollen. Below 88 cm. a pollen composition typical of zone VI is recognizable, and between 103 and 150 cm. we find the triple sequence of sandy clay, organic mud and gravel. This recalls the mineral—organic—mineral sequence of deposits of the Allerød oscillation. The samples from the sandy clay contain quite large amounts of *Quercus* and *Ulmus* and large percentages of *Corylus*.

Recounts made by Miss Andrew of the three samples from the lower nekron mud gave the results in table 5.

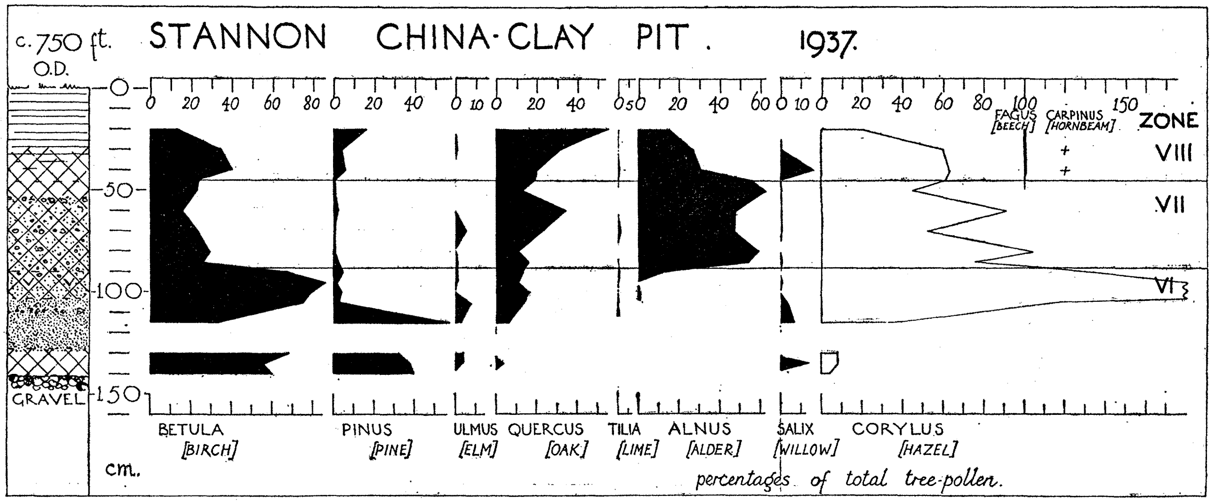

FIGURE 24. Pollen diagram: Stannon china-clay pit, Bodmin Moor, Cornwall.

TABLE 5

	A	B	C
Betula	60	56	68
Pinus	40	36	32
Ulmus	—	4	4
Quercus	—	4	—
Corylus	4	8	8
Salix	—	14	—
Gramineae	104	148	204
Cyperaceae	104	150	372
Alisma plantago	—	4	—
Armeria	—	2	4
Artemisia	48	48	28
Botrychium	—	6	8
Campanula	—	—	12
Caryophyllaceae	20	26	32
Chenopodium	—	4	—
Compositae	36	34	24
Empetrum	20	—	52
Ericoid pollen	24	40	16
Epilobium	8	2	8
Filicales	—	6	—
cf. *Filipendula*	24	4	8
Galium	—	8	—
Helianthemum	+	+	—
Menyanthes	12	+	4
Myriophyllum alterniflorum	28	24	4
cf. *Ononis*	—	2	—
Plantago	—	4	4
Ranunculus	—	6	—
Scabiosa	4	4	24
Sparganium	4	—	4
Thalictrum	16	6	12
Typha latifolia	4	+	—
Umbelliferae	12	32	28
Valeriana	12	6	24
Sphagnum	312	170	260

(The results are given as percentages of total tree pollen. Samples A and C are based on counts of twenty-five-tree pollen, and B upon fifty.)

It will be seen that although there is a little *Quercus*, *Ulmus* and *Corylus* pollen, the ratio of non-tree pollen to tree pollen is high, and there are many of the genera typical of the open late-Glacial park-tundra, particularly *Armeria*, *Artemisia*, *Thalictrum*, *Helianthemum* as well as *Empetrum*, *Scabiosa*, *Valeriana*, *Campanula*, *Botrychium* and *Myriophyllum alterniflorum*.

This might be taken to indicate that the lower nekron-mud is indeed referable to zone II, with the sandy clay referable to zone III. It is evident, however, that such a conclusion could only follow much more detailed investigation.

(*b*) *Hawks Tor china-clay pit: upper peat* (figure 25)

The samples which yield the pollen diagram of figure 25 are those collected by H. Godwin in 1936, the stratigraphy of which has already been described (§ 2*a*, p. 404). It was from this actual site that the earliest samples for macroscopical analysis were collected at the same time.

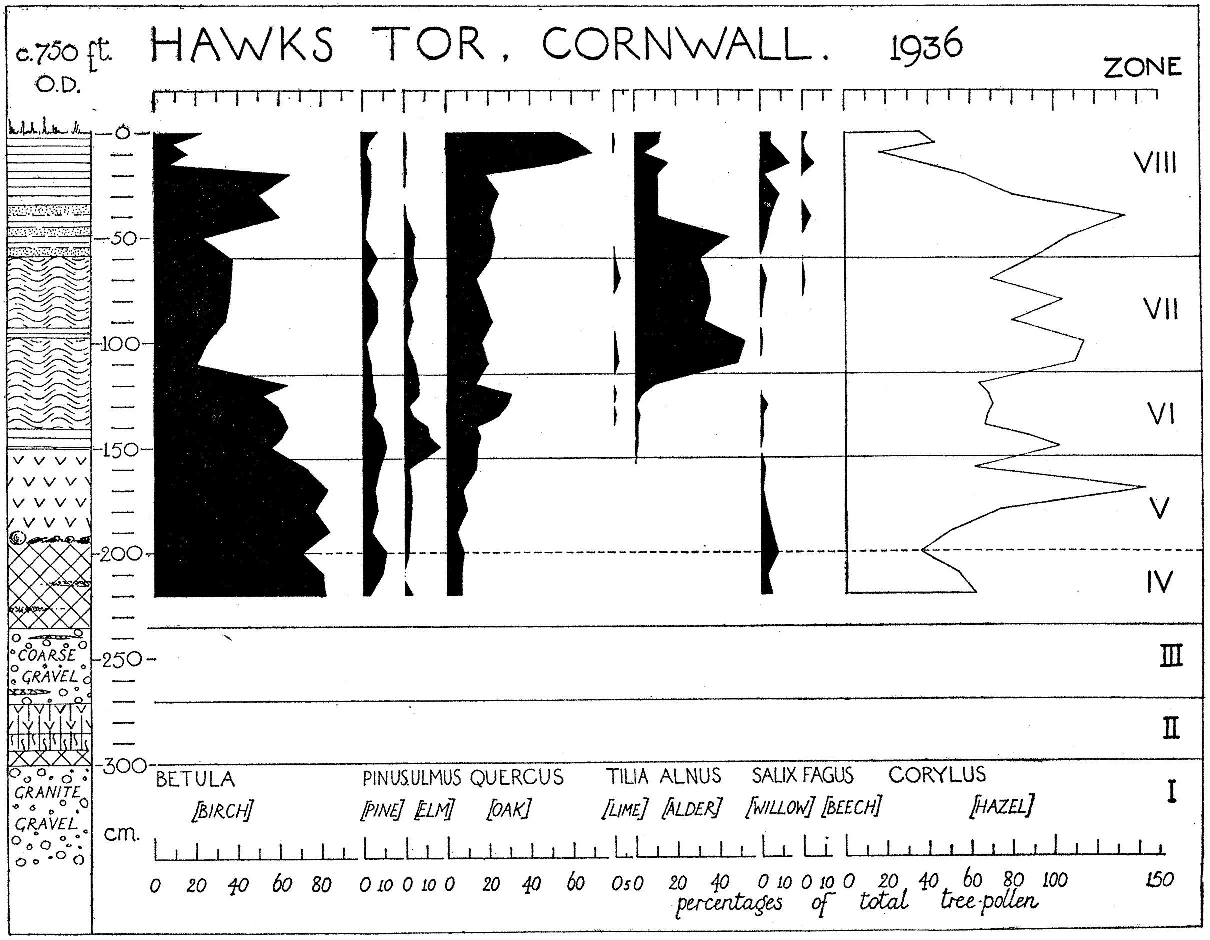

FIGURE 25. Pollen diagram: Hawks Tor china-clay pit, Bodmin Moor, Cornwall.

The pollen samples were prepared and analyzed by Mrs Megaw. Certain zones may be identified with assurance. At 60 cm. there is an abrupt change from crumbly weathered homogeneous peat to fresh, paler *Molinia* peat, and this may be regarded as the opening of zone VIII which corresponds with the sub-Atlantic climatic period. The numerous changes of the pollen curves at this level accord with this view, especially the decrease of *Alnus* and *Tilia* (and shortly afterwards of *Ulmus*) as well as the increase in *Fagus*. These are all features already found at this transition in many Somerset diagrams (Clapham & Godwin 1948). The thin seams of sand and silt in the lower part of the fresh *Molinia* peat may well be related to the sudden climatic worsening which is represented in the Somerset peat profiles by the most pronounced flooding horizon.

There can be little doubt that the boundary between zones VI and VII must lie at 115 cm., where the sudden rise of *Alnus* is manifest. This restricts the higher frequencies of *Tilia* and *Alnus* pollen to the zone between 60 and 115 cm., where the post-Glacial climatic optimum must lie. This we may call zone VII. It is not possible to distinguish the transition zone VII–VIII.

It is by no means evident where the lower boundary of zone VI should be placed. If we choose 155 cm. on the basis of the sudden and substantial increase of *Ulmus*, we have to accept that quite substantial amounts of *Quercus* and *Ulmus* are present in zone V along with the customary high *Corylus* values. This does not, however, conflict with the zoning already given for Parsons Park, Dozemare Pool and Stannon Marsh.

Although we have indicated that 200 cm. marks the transition between zones IV and V, it remains doubtful whether zone IV can indeed be detected at the base of this diagram, on account of the considerable values of elm, oak and hazel pollen at this fairly high altitude. The non-tree pollen is also not high in proportion to total tree pollen.

Details of the non-tree pollen and spore content of the lowest seven samples of the upper peat (65 to 125 cm.), together with the sample at 160 cm., are given in table 6, p. 448, which gives Miss Andrew's recount in 1948 of the original slides. It will be noted that pollen frequencies are not expressed as percentages of total tree pollen, but as percentages of all pollen except obvious hydrophytes and except bryophyte and pteridophyte spores. It is of particular interest to find pollen of *Lonicera* (honeysuckle) in the samples of zone V along with that of *Hedera* (ivy); one grain of *Lonicera* is even present at 220 cm. Other non-tree pollen includes that of *Succisa pratensis* from samples throughout zone V and the one sample from zone VI, of *Valeriana officinalis* from samples in zone V and from the sample at 220 cm. Sparse *Epilobium* and *Artemisia* pollen occurs also in the lower samples of the upper peat. The *Artemisia*, *Scabiosa* and *Valeriana* along with some of the other herbaceous types are elsewhere known as constituents of the late-Glacial flora and presumably indicate fairly open vegetation.

The attribution of zones I, II and III in figure 25 follows the stratigraphy and is more fully discussed in the next section.

At site 42A in the lowest sample (11) of the series at the base of the upper peat (table 7, p. 450), Miss Andrew has again found much pollen of *Lonicera* and frequent pollen of *Hedera helix*, together with one well-preserved grain of *Tilia cordata*. As will be seen from the table, this is at the level of considerable expansion of the *Corylus* pollen, and this, together with the small amounts of *Quercus* and *Ulmus* pollen, suggests reference to the opening of zone V, but it is not impossible that here as at site 36 the base of the upper peat may belong to zone IV.

(*c*) *The post-Glacial zonation*

Whilst little difficulty exists in recognizing zones VI, VII and VIII in the Cornish diagrams, and in agreeing that deposits of zone V precede them, there is clearly some difficulty with zone IV and its relation to zone V.

If we accept the view that the Allerød oscillation is represented in the Hawks Tor series by the lower peat and the gravel layer overlying it, then we have to decide whether there is or is not any time gap (any unconformity) between the Allerød beds and the overlying organic deposits. If we decide that a gap might indeed be present, then the organic deposits which follow the Allerød deposit of zone III could well be as late as zone V. If, however, there is no time discontinuity in the series, then the organic deposits over the mineral beds of Allerød zone III must belong to zone IV, and in that event we must recognize that in this south-western corner of Britain the warmth-demanding trees are in evidence sooner than they are elsewhere.

The evidence which will enable us to choose between these alternative views is (i) stratigraphic, (ii) pollen-analytic.

It may be said at once that (at Hawks Tor where alone detailed investigations were made) no indications of stratigraphic discontinuity were remarked in the field by the independent observations of the three authors. Further, the pollen-analysis results seem to show much affinity in composition between the basal samples of the upper peat and the peaty seams within the intermediate sands and gravels. This affinity of pollen composition can be seen in tables 6 and 7, and is similarly evident in the lower peat at Parsons Park (table 5).

At Parsons Park late-Glacial herbaceous pollen types occur in a tree-pollen sequence suggestive of zone IV, and immediately above the gravel.

At Hawks Tor the base of the upper peat in both site 36 and site 42A contains this same characteristic assemblage.

In each of these instances the stratigraphic relation could be held to indicate that the deposit was close to the late-Glacial, representing in fact that first laying down of organic muds after the countryside recovered its vegetational carpet after cryoturbatic soil disturbances of zone III. If so these layers must be regarded as belonging to zone IV.

Although the hypothesis that the base of the upper peat indeed belongs to zone IV can be thus supported, it must be noted that a possibility remains that the immediate sands and gravels may represent not only zone III, but also part or all of zone IV. There is little, however, in the records of Allerød stratigraphy elsewhere in western Europe (even in Ireland) to support such a view.

We are therefore forced to accept the possibility that zone IV is, indeed, represented at Hawks Tor in the base of the upper peat, and that zone IV in this south-western peninsula has a rather stronger element of warmth-demanding trees than it has in most parts of England and Wales. This is not altogether surprising, and in Old Decoy (Cambridge, Godwin 1940*b*) and at Hockham Mere (Norfolk, Godwin 1944) a similar situation has been revealed.

(*d*) *Hawks Tor china-clay pit: lower peat*

In 1936, as part of the same vertical series as that shown in the pollen diagram (figure 25), samples were collected through the organic muds and peats beneath the solifluction gravel, and the pollen content of these samples was investigated by Mrs Megaw in 1937. By 1948, however, our knowledge of the importance of the pollen of the herbaceous flora of the late-Glacial had much increased, and Miss Andrew was able to make a very careful recount of the slides originally prepared by Mrs Megaw. The results are set out in table 6, which has

TABLE 6. HAWKS TOR, SITE 36

	lower peat (cm.)							upper peat (cm.)							
	30	25	20	15	10*	5	0	220	210	200	190	180	170	160	125
Betula	6·8	+	29	11	9	1·6	5·7	31	24	37	40	28	26	43	7·8
Pinus	+	—	—	—	—	—	0·9	1·5	3	4·6	3	1·5	0·7	4	1
Ulmus	—	—	—	—	—	—	—	—	—	—	0·4	1	1·2	4	1·6
Quercus	—	—	—	—	—	—	—	+	7	—	0·9	4	1·2	4·3	4·1
Alnus	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0·9
Corylus	—	—	—	—	—	—	—	51	18	40	29	48	61	30	23
Salix	—	—	8	—	20	1·6	1·5	—	6	2·5	4	5	2	3	0·1
Cyperaceae	42	38	36	55	—	58	65	—	9	5·5	4·5	1·5	0·07	2	47
Gramineae	38	50	16	—	25·5	8	14	12	15	4·6	14	8	1·2	2	10
Armeria	—	+	—	—	—	—	—	—	—	—	—	—	—	—	—
Artemisia	4·4	4	—	+	—	1·6	0·9	+	+	—	0·2	—	—	—	—
Atriplex	—	+	—	+	—	1·6	1·5	+	+	—	0·9	—	0·3	—	—
Caryophyllaceae	+	—	+	—	2	—	0·9	—	+	+	—	0·1	0·07	—	—
Chenopodium	—	—	—	—	—	—	—	—	—	+	—	—	—	—	—
Compositae	2	8	3	22	—	5	2·4	+	—	+	—	0·1	—	0·4	—
Epilobium	—	+	+	+	—	1·6	+	+	+	—	—	—	—	—	—
Ericoids†	—	—	—	—	—	1·6	0·9	1·5	5	2·5	1	0·5	0·3	3	3·4
cf. *Filipendula*	—	—	—	—	—	—	—	—	—	—	—	0·6	0·1	—	—
Galium	—	—	—	—	5·5	—	1·5	—	—	—	0·2	—	—	—	—
cf. *Hedera*	—	—	—	—	—	—	—	—	—	—	+	—	0·07	—	0·4
Helianthemum	—	+	3	—	—	—	—	—	—	—	—	—	—	—	—
Labiatae (6 furrowed)	—	—	—	—	—	1·6	—	—	—	—	—	—	—	—	—
cf. *Ligustrum*	—	+	—	—	—	—	—	—	—	—	—	0·2	0·07	—	—
Lonicera	—	—	—	—	—	—	—	1·5	—	—	0·2	—	0·5	1	—
Montia	+	—	—	+	—	+	+	—	+	—	—	—	—	—	—
Plantago	—	—	—	—	—	—	—	—	+	—	—	—	—	—	—
Polemonium	—	+	—	—	—	—	—	—	—	—	—	—	—	—	—
cf. *Ranunculus*	6·8	—	—	11	38	1·6	0·9	—	2	—	—	0·7	0·1	1	—
Scabiosa	—	—	—	—	—	—	—	—	2	0·4	0·2	0·2	2	4·3	0·2
Thalictrum	+	—	3	—	—	1·6	1·5	—	—	—	—	—	—	—	—
Umbelliferae	—	—	—	—	—	11	2·4	1·5	—	0·4	0·9	1	0·5	—	0·1
Valeriana	—	—	—	—	—	3·6	+	+	—	1·2	0·2	0·2	—	—	—
Alisma plantago	—	—	—	+	—	—	—	—	—	—	—	—	—	—	—
Myriophyllum alterniflorum	315	820	260	508	55	1·5	3	+	—	0·4	0·5	—	—	—	—
Nymphaea	—	—	—	—	2	—	—	—	—	—	—	—	—	—	—
Potamogeton	7	35	7	—	—	3	1	—	—	—	—	—	—	—	—
Sparganium	38	65	48	167	21	5	3	—	—	—	—	—	—	—	—
Filicales	—	—	—	—	—	—	1·5	5	14	15	17	3	49	112	3
Polypodium	—	—	—	—	—	—	—	+	—	0·4	—	0·2	3·5	5·5	1·5
Selaginella	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—
Sphagnum	—	—	—	—	—	+	5	15	14	12	3	—	2	3	24
counted totals	47	23	27	9	55	63	122	74	58	238	555	828	1414	256	1000

(The results are given throughout as percentages of the total of tree, shrub and land flowering plants pollen, the counted totals for which appear at the bottom of the columns (see text, p. 449).)

* Mrs Megaw's original count from which Cyperaceae were intentionally omitted.
† *Empetrum* pollen is included in the ericoid pollen total, but see also p. 453.
\+ indicates presence in the material but not in the counted traverses.

already been noticed, since the recounts extended also to the lower layers of the upper peat (see § 5*b*).

The generally unforested conditions of the period concerned make it rather uninformative to express the results merely as percentages of total tree pollen, and in order therefore to convey more readily a sense of the character of the prevalent land vegetation, the results have been expressed as percentages of a total which includes tree pollen and pollen of all groups of flowering plants not evidently aquatic. It excludes besides aquatic flowering plants, *Sphagnum* spores, other moss spores and the spores of Pteridophyta.

It may be noted that for all the genera recognized in the 1937 counts there is good agreement between the results obtained by Mrs Megaw and Miss Andrew.

The lower peat of the Hawks Tor 1936 series shows several features which suggest that it was deposited in zone II.

(i) The 'tree' pollen is restricted to *Betula*, *Pinus* and *Salix*, with *Betula* decidedly the most abundant of the three.

(ii) There are present non-tree pollen and spores of genera shown by Iversen (1946, 1947*a*), Jessen (1949) and others to be characteristic of the late-Glacial period and its open 'Park tundra', viz. *Armeria*, *Artemisia*, *Botrychium*, *Empetrum*, *Helianthemum*, *Selaginella* and *Thalictrum*. Another species of similar but less pronounced significance is *Myriophyllum alterniflorum*; since anther clusters of this plant were also identified it is not surprising that in the lower muds which represent the open-water phase of the channel's history, very large percentages of its highly recognizable pollen should have been encountered.

(iii) There are present pollen grains of species which, although not yet generally recognized as typical of the late-Glacial vegetation, have in fact been found in late-Glacial deposits elsewhere in Britain (particularly in unpublished counts from the Lea Valley, Essex-Hertfordshire). These include a single grain of the readily identifiable genus *Polemonium*, now of very restricted natural distribution in Britain (see § 4*a*), *Epilobium* and *Valeriana*. In addition, we should mention the grains referred to as 'cf. *Ligustrum*'; it seems improbable that these really refer to the genus *Ligustrum*, but the precise identification is still lacking. The grains of *Montia* now identified by Miss Andrew for the first time in British late-Glacial beds may later fall into the category of late-Glacial indices; their occurrence is interesting since the seeds of *Montia fontana* have already been recognized (§ 4*a*).

(iv) Certain categories of grains are present in fair amount, but can only be referred to the family, e.g. Umbelliferae, Labiatae, Caryophyllaceae, Compositae, or to a genus which contains several species, e.g. *Atriplex*, *Chenopodium*, *Galium*. Taken with the pollen of herbaceous plants already mentioned, these, although not closely identifiable, nevertheless constitute a characteristic *assemblage* of species which could be characteristic only of rich herbaceous vegetation of open (unforested) habitats.

(v) The same point is established by the relatively high ratio of tree pollen to non-tree pollen. In these samples from the lower peat the tree pollen amounts only to 3 to 37 % of the total pollen of the non-aquatic flora. By contrast, in the lower samples of the upper peat, 56 to 83 % of the total 'non-aquatic pollen' comes from the trees. Of course, sedge and grass pollen constitute a large part of non-tree pollen, and to a certain extent this may be influenced by local vegetational development within the channel, as, indeed, the records of *Carex* fruits indicate. All the same the general open character of the vegetation is evident, and it will be remarked that ericoid plants played little part in it; this agrees closely with Iversen's conclusions for southern Scandinavia.

These analyses of the lower peat at Hawks Tor, site 36, have been supplemented by counts of a second series collected by A. P. Conolly in 1942 (site 42A). This latter series consists of eleven samples, the lower seven within the bottom peat, the next three in the gravelly soil and the eleventh in the base of the upper peat. The pollen counts of this series were made by Miss Andrew and are set out in table 7, expressed in the same terms as table 6.

TABLE 7. HAWKS TOR, SITE 42A

	lower peat							gravelly-soil			base of upper peat
sample no. (see text) ...	I	II	III	IV	V	VI	VII	VIII	IX	X	XI
Betula	9	2·5	2	—	1	11	13	8	9	30	32
Pinus	1·8	—	0·7	—	—	—	1·4	3	6	6	1·7
Ulmus	+	—	—	—	—	—	—	+	—	—	0·6
Quercus	—	—	—	—	—	—	—	—	—	—	2
Corylus	—	—	—	—	—	+	—	1·3	1	12	55·6
Salix	—	—	—	—	—	+	0·7	—	1	0·6	—
Cyperaceae	30	60	38	14	86	65	25	16	15	1	—
Gramineae	21	2·5	30	33	6	3	19	36	16	27	6
Armeria	—	—	—	—	—	—	—	—	—	+	+
Artemisia	2·7	+	+	2	1·4	0·9	+	3	10	1	—
Atriplex	+	—	—	2	0·2	—	1·4	—	—	0·3	0·3
Caryophyllaceae	3·5	2·5	+	1	+	0·5	2·7	4	6	1·1	—
Chenopodium	—	—	—	1	—	0·5	—	—	—	—	—
Compositae	4·4	20	7	8	1·4	4	3	3	15	6	—
Epilobium	0·9	+	0·7	3	+	0·5	1·4	3	1	1·1	—
Ericoids*	9·8	—	+	—	+	+	15·4	17	10	7	—
cf. *Filipendula*	1·8	—	—	—	—	0·5	3	1·3	—	0·6	—
Galium	1·8	—	—	—	1	0·9	2	—	—	—	—
Helianthemum	—	—	+	+	—	+	+	—	—	—	—
cf. *Ligustrum*	—	—	—	—	+	+	—	—	—	—	0·3
Lonicera	—	—	—	—	—	—	—	—	—	—	0·3
Montia	—	—	—	—	+	+	—	—	—	—	—
Plantago	—	2·5	2	—	—	—	—	—	—	—	—
Polygonum cf. *bistorta*	—	—	—	—	—	—	—	—	2	+	—
cf. *Ranunculus*	2·7	10	17	29	0·7	0·5	1·4	—	+	0·6	0·3
Rumex	—	—	—	+	—	—	—	+	—	—	—
Scabiosa	3·5	—	—	—	—	0·5	2	4	—	+	0·8
Thalictrum	2·7	—	—	—	0·4	1·4	+	1·3	1	0·3	—
Umbelliferae	4·4	—	—	—	2	3	6	1·3	2	4	—
Valeriana	+	—	—	—	+	2	2·7	1·3	+	1·1	—
Myriophyllum alternif.	4·4	440	80	46	—	+	—	—	—	—	—
Sparganium	—	22·5	47	15	0·7	—	—	—	—	—	—
cf. *Sparganium* sp.	—	92	8	—	0·2	—	—	—	—	—	—
Typha latifolia	—	—	—	—	0·2	—	2·7	+	—	0·3	0·3
Filicales	—	—	—	—	—	—	—	—	—	+	+
Botrychium	—	+	+	+	—	+	—	—	—	—	—
cf. *Osmunda*	—	—	—	—	—	—	—	—	—	+	—
Polypodium	—	—	—	—	—	—	—	—	—	+	6
Sphagnum	9	+	+	1	+	0·5	27	17	3	12	21

* *Empetrum* pollen is included in the ericoid pollen total, but see also p. 453.
\+ indicates presence in the material but not in the counted traverses.

Leaving aside the uppermost sample and considering first the results as a whole, it will be apparent that those general indications of late-Glacial age exhibited by the series from site 36 are also present here. There is the almost complete restriction of the tree pollen to *Betula* and *Pinus*, the great overweighting of non-tree pollen in relation to tree pollen, and the presence of virtually the same list of pollen and other spores of herbaceous species typical of late-Glacial vegetation. There is no need to recapitulate the long list, but we may note that to it must be added *Plantago maritima*, *Succisa* (present in the base of the lower peat at site 36), *Rumex* and *Polygonum* cf. *bistorta*. These serve further to emphasize the general open character of the vegetation. *Montia* pollen recurs in this series.

It will be seen in the second place that the results show some pronounced variation through the succeeding layers. Sample I from the surface of the lower gravel resembles in pollen content the samples VI to X, which include the upper gravels. The intermediate samples reflect the vegetational history of the channel itself, through the shallow open-water stages in which pollen of aquatic plants very strongly preponderates, especially that of *Myriophyllum alterniflorum*, although *Sparganium*, *Potamogeton* (see p. 456) and *Typha angustifolia* are also important. In sample V the very high value for cyperaceous pollen indicates consolidation of the depression by Caricetum. In the succeeding samples pollen of herbaceous dicotyledons becomes preponderant, a single *Ulmus* (very fresh) is present in VIII, and *Corylus* and *Salix* appear in small amounts from VI to IX. It is of much interest to note that the transition from sample IX to XI shows a remarkable inversion of the ratio of tree to total non-tree pollen, whilst at the same time the proportion of *Corylus* rapidly increases. These changes coincide with the stratigraphic boundary at the top of the lower gravel, and it is difficult to avoid the conclusion that the same climatic improvement was responsible for all the phenomena. Point is given to this suggestion by the appearance in sample XI of pollen not only of *Quercus* and *Ulmus* but also of *Lonicera*, and in sample X of a single spore of *Osmunda*. *Polypodium* spores appear first in X, are abundant in XI, and may also be related to the spread of woodland.

(*e*) *Late-Glacial pollen and spores*

Alisma plantago-aquatica L.

One pollen grain resembling that of *A. plantago-aquatica* was identified from the zone II muds of the Hawks Tor 36 series, and two from the lower muds at Stannon Marsh. The species extends to the Arctic.

Arctium (see Compositae)

Armeria

The calyces of *Armeria* have often been recognized in subfossil state, and some rather inconclusive attempts at specific identification have been based upon their characters. In 1940 Erdtman drew attention to the condition of floral dimorphism in *Statice armeria* L. in which some plants bore 'cob-like' stigmas and coarsely reticulate spinous pollen grains (type A), whilst others bore 'papillate' stigmas and more finely reticulate pollen (type B). In the same year Iversen (1940) drew attention to the fact that the very homogeneous genus *Armeria* can be separated into two groups very distinctly different, in that one (of European-Mediterranean distribution) is dimorphic and parasterile, whilst the other, which includes the holarctic form of northern America and Asia, has only monomorphic self-sterile species in it. *A. vulgaris* Willd. is shown to be dimorphic and to include the Atlantic and maritime var. *maritima* and the mountain var. *alpina*. On the other hand, the nearest holarctic

Armeria, *A. labradorica*, which now exists in northern Greenland, is monomorphic. In view of these facts it is of particular interest to note not only that *Armeria* pollen occurs in these late-Glacial Cornish deposits, but that since both A and B types of pollen occur, the dimorphic species was present. The same condition is found in late-Glacial deposits in the Lea Valley where calyces also occur, and in the Irish late-Glacial.

The pollen may thus be referred in all probability to *A. vulgaris* s.l. (Iversen), and its presence undoubtedly indicates open conditions.

Artemisia

The pollen of *Artemisia*, long confused with that of *Salix*, has been recently shown to be in fact readily distinguishable, and many workers have now established it as an indicator species of high value (Erdtman 1943; Iversen 1941). It has been shown to be present in characteristically large frequencies in late-Glacial deposits and, very much later, in Neolithic and post-Neolithic sediments when forest clearance by human agency had taken place (Firbas 1948; Iversen 1947*a*).

Although we cannot say from which species the pollen was derived it seems certain that high pollen frequencies indicate unforested areas and very likely broken or open soil. Some species at least of *Artemisia* reach arctic latitudes.

Artemisia pollen is present in small amounts throughout the deposits we have referred to zones II and III, and persists into zone IV in the Hawks Tor 36 series. In the lower organic muds at Stannon Marsh *Artemisia* pollen is about half as abundant as the total tree pollen.

Atriplex

It seems possible to distinguish pollen of *Atriplex* from that of other chenopodiaceous genera, although the species remain unrecognizable. This pollen type occurs in small frequency throughout zones II and III of the Hawks Tor 42A series, and extends into zones IV, V and VI. The genus is characteristic of maritime and ruderal habitats, but both categories are strikingly open ones.

Botrychium lunaria (L.) Sw.

The very thick-walled, heavily warty, rounded tetrahedral spores of this fern occurred in the lower muds at Stannon Marsh and in the lower muds and peats of zone II at Hawks Tor. This is another species of widespread occurrence in Britain to-day, whilst ranging into the Arctic. It is characteristic of open habitats, and its spores have been recognized already in late-Glacial deposits in Denmark (Iversen 1946, 1947*a*).

Calluna vulgaris (L.) Hull

A low frequency of *Calluna* pollen tetrads has been found in zones II and III of the Hawks Tor 42A series. In Eire, Jessen does not report *Calluna* earlier than zone IV, but scarce grains have been reported in late-Glacial deposits by Iversen (1946) and Faegri (1945).

Carlina (see Compositae)

Campanula

A few of the very characteristic pollen grains of this genus were found to occur in the lower muds at Stannon Marsh. Several British species of *Campanula* have pollen grains of the same approximate size as the fossil grains and they are not morphologically distinguishable. Similar pollen, together with seeds of *Campanula*, has been found in late-Glacial beds in the Lea Valley also (unpub.).

Caryophyllaceae

Pollen of the characteristic caryophyllaceous type is fairly frequent throughout the late-Glacial layers at Hawks Tor, with greater abundance in the gravelly soil of zone III. Seeds of members of the family have been identified from zone II, but unfortunately up to the present the pollen has not been referable to genera or species, although the types '*Silene*', '*Lychnis*', '*Cerastium*' and '*Arenaria*' can be tentatively recognized.

Chenopodium

Pollen of *Chenopodium* has been identified from zones II and IV at Hawks Tor, and also from the lower Stannon Marsh muds. As with *Atriplex*, its presence carries with it the implication of open habitat conditions; it has been identified as a component of the ruderal and weed flora which spread with post-Glacial forest clearance.

Compositae

Although not separately shown in the lists, the Compositae pollen included several types. The majority fall into the three groups: (1) '*Crepis*' or '*Taraxacum*' type, (2) '*Matricaria*' type or (3) '*Senecio*' type. In the two Hawks Tor series these occur through zones II and III.

Genera bearing pollen of the '*Matricaria*' type include *Matricaria*, *Anthemis*, *Chrysanthemum* and *Achillea*. Although the various British species of these genera have pollen of different sizes the ranges overlap, nor do the morphological characteristics of the pollen grains at present suffice for closer identification.

An '*Arctium*' type pollen is yielded by the British species of *Arctium*, by *Carlina vulgaris* and *Onopordon acanthium*. These grains from Hawks Tor 42A (zone IV) and Hawks Tor 36 (zone II) closely resemble, however, those of *Arctium* itself, although they cannot be referred to any particular species. A single grain from Hawks Tor 42A (zone IV) closely resembles *Carlina* pollen, but does not correspond precisely with any samples yet examined from species of *Carlina* now living in Britain; one would of course expect it to be of *C. vulgaris*.

In the Hawks Tor series 42A (zone II) there was found a single grain of the '*Cirsium*' type, a discovery of interest because of the identification of fruit of *Carduus nutans* or *C. crispus* from the *Carex*-wood peat, 42A (see § 4*a*, p. 413).

Empetrum nigrum L.

Empetrum pollen tetrads occur frequently in these Cornish late-Glacial deposits (Parsons Park, 210 cm., zone IV; Stannon Marsh—the lower muds—table 4; Hawks Tor, 42A, zones II and III; and Hawks Tor 36, zones II, IV and V). Erdtman (1938) and Faegri (1945) have shown that by shape and size it is possible to separate *E. nigrum* s.s. from *E. hermaphroditum* Hagerup, the more northern polyploid. As Jessen has recognized for the very abundant late-Glacial *Empetrum* pollen in Ireland, so in Cornwall there is little doubt that the species represented is exclusively the former. In Eire it is given from zones I to V and there, as in Cornwall, the pollen is accompanied by fruit-stones (see § 4*a*).

Epilobium

Very large and striking grains of *Epilobium* have been recorded from zones II, III and IV of the two Hawks Tor series and from all three samples of the lower muds at Stannon Marsh. Similar references to *Epilobium* pollen are made by Jessen in zones II, IV and VII*a* from Ireland. On several occasions Iversen refers to discoveries of '*Chamaenerion*' in late-Glacial deposits in Denmark, without mention of other pollen of *Epilobium* type. It may therefore be that in Cornwall we also have to do with *Chamaenerion angustifolium* L. (= *Epilobium angustifolium* (L.) Stop.), but we have not thus far felt able to refer the fossil pollen to any particular species, excellently though some of them are preserved. *Chamaenerion* pollen forms part of the surface pollen catch in the tundra of northern Labrador still (Wenner 1947).

Filipendula cf. *ulmaria* (L.) Maxim

Pollen of *Filipendula* cf. *ulmaria* occurs in zones II and III of the Hawks Tor series, and a few grains extend into zone V; they occur also in the Stannon Marsh muds. In the Lea Valley the same pollen type occurs in late-Glacial deposits with the characteristic fruits of *F. ulmaria*, and the weight of probability is that this is the species concerned. The same identification of pollen as *Filipendula* cf. *ulmaria* is made by Iversen (1946) for zones II and III at Bromme, and Jessen records the fruits from Ireland in zone II also.

Galium

The readily recognizable hexacolpate or heptacolpate grains of *Galium* occur in zones II and IV of the Hawks Tor series. The presence of this pollen type in late-Glacial deposits has been noticed by Erdtman (1946) and Iversen (1946).

Helianthemum

Since the publication by Iversen of his paper (1944*b*) on *Helianthemum* as a fossil Glacial plant in Denmark, pollen of this genus has been rather widely recognized in late-Glacial deposits. Iversen gave reasons for referring the Danish fossil material to the species *H. oelandicum* (L.) Willd. At much the same time Welten (1944) and Lüdi (1944) showed that the treeless late-Glacial period of Switzerland was characterized by frequent pollen of the related *H. alpestre*. Mitchell (1948) has identified pollen of the genus in late-Glacial layers at Whitrig Bog, Berwickshire, and such certainly occurs elsewhere in late-Glacial deposits in Britain.

Helianthemum pollen occurs sparsely in zones II and IV of the Hawks Tor series, and in two of the samples of the lower muds at Stannon Marsh. Whilst identification of the genus is certain, there is no means of absolute identification of the species. In size the grains correspond with *H. canum* or the lower end of the size range of *H. chamaecistus*. As the former has now such a restricted distribution in Britain (and also stands closer to *H. oelandicum*) it would be of great interest if exact identification of the fossil pollen could be achieved.

Labiatae

Pollen of the Labiatae family falls into two main groups, one hexacolpate and the other tricolpate. The former is produced by the genera *Galeopsis* and *Lycopus* among others, and occurs in zone II of the Hawks Tor 36 series. A *Lycopus* nutlet was found in zone II of the Hawks Tor site 36 (see § 4*a*).

Menyanthes trifoliata L.

Pollen of *Menyanthes* was found in two of the samples of the Stannon Marsh lower muds. Its seeds are well known from late-Glacial layers, including those at the Cornish Hawks Tor sites.

Montia

The highly recognizable small dodecacolpate grains of *Montia* were found sparsely throughout zone II and in zone IV at Hawks Tor. Their recognition is of especial interest because of the identification of *Montia* seeds mentioned already (§ 4*a*, p. 419). Iversen (1942) has already mentioned the recognition of a single grain of *Montia* in the upper *Dryas* layers (zone III) at Nørre Lyngby.

Myriophyllum alterniflorum DC.

The very striking pollen of this free-floating aquatic plant has been found in great abundance in the open-water phases which form the lower part of the Hawks Tor basin mud and peat (zone II) and in small amount in zone IV above. The pollen is also present at the base of the Parsons Park series. For comment on the associated fruit identifications and phytogeographical status of the plant, see § 4*a*, p. 421.

Nymphaea

A single grain of *Nymphaea* pollen was found in zone II of the Hawks Tor 36 series. It is not possible to say whether it should be referred to *N. alba* L. or to *N. occidentalis* (Ostenf.) Moss. *Nymphaea* has been found in Ireland and on the European mainland also in zone II.

Osmunda regalis L.

A single grain of *O. regalis* was found at the base of the upper peat in the Hawks Tor 42A series (zone IV). Jessen does not record this species before zone V in Ireland.

Plantago

A few grains of *Plantago* were identified from the lower muds at Stannon Marsh, and one from the base of the upper peat in the Hawks Tor 1936 series (zone IV). They were referred to *P. maritima* with some confidence; it has been pointed out by Iversen (1941) that the west European species of *Plantago* can be recognized fairly easily, and *P. lanceolata* has been extensively used since then as an index of Neolithic and post-Neolithic forest clearance.

P. maritima is of course familiar in Britain in inland (mountain) stations as well as marine, but like the genus as a whole indicates an open type of habitat.

Polemonium

The discovery of a single grain of this genus from zone II of the Hawks Tor 36 series is commented on in § 4*a*, p. 422.

Polygonum cf. *bistorta* L.

From the upper part of zone III in the Hawks Tor 42A series several grains of *Polygonum* were tentatively referred to *P. bistorta* L. Although *P. viviparum* pollen has been recognized in late-Glacial deposits (Iversen 1946), *P. bistorta* seems not to have been. Both species extend to the Arctic.

Polypodium vulgare L.

The very recognizable spores of *P. vulgare* occurred at the top of zone III and the base of zone IV in the Hawks Tor 42A series. Jessen has identified them in Ireland from zone III onwards. It has a high altitudinal range in Britain and extends to the Shetlands.

Potamogeton

Although Iversen (1946) has drawn attention to the possibility of separating the pollen of *Potamogeton* into the two types of the wind-pollinated and water-pollinated species, we were unable confidently to make this separation. Substantial amounts of pollen referable to the genus were identified in the zone II muds along with fruit stones. It is likely that the percentages of *Potamogeton* pollen in the Hawks Tor series are underestimated, as the delicate pollen is often too damaged to be certainly identified.

Ranunculus

Ranunculus pollen occurs in the lower muds at Stannon Marsh, at the base of the Parsons Park series, throughout zones II and III of the Hawks Tor series, and on into the post-Glacial zones. Although it is unlikely that one can in fact recognize the pollen of different species of *Ranunculus*, it is interesting to note that much of this Cornish pollen appeared to correspond with *R. lingua* L. *Ranunculus* fruits, of which one was *R. flammula*, were also present. It may be noted that Iversen (1946) records late-Glacial pollen as *Ranunculus* cf. *lingua* from Bromme, and that Jessen records *R. lingua* fruits from zone II in Ireland.

Rumex

Rumex pollen has been recorded elsewhere in substantial frequencies in the late-Glacial, so that records from zones II and III of the Hawks Tor series are not remarkable. For macroscopic remains, see § 4*a*, p. 423.

Succisa pratensis Moench. (*Scabiosa succisa* L.)

Grains of *Scabiosa* corresponding precisely with those of *Succisa pratensis* except for somewhat smaller size, were found at the base of the Parsons Park series, throughout the Stannon Marsh lower muds, in zones II, III and IV of the Hawks Tor 42A series and through zones IV and V of the Hawks Tor series 36. Jessen has recorded this pollen from zones II, VI and onwards in Ireland, and in western Norway Faegri (1943) mentions frequent *Succisa* pollen as first appearing in pre-Boreal deposits. This plant reaches high altitudes in Britain and has an arctic distribution. The extension of its pollen through zones IV and V suggests that at least locally near the depressions open habitats were preserved.

Selaginella selaginoides (L.) Link

A microspore of this most characteristic late-Glacial plant was found in the pollen slides of the Hawks Tor 36 series at the top of zone II.

Jessen records the species from Ireland in zones II and III as well as later.

Sparganium

Pollen of *Sparganium* occurs throughout the lower muds (zone II) at the two Hawks Tor sites, sometimes in considerable abundance, a fact which accords with the identification of *Sparganium* fruits. Iversen (1946) records *Sparganium* pollen from the Danish late-Glacial, and Jessen (1949) gives Irish records for fruits of *S. minimum* and *S. simplex* in zone II and *S. ramosum* in zone III.

Thalictrum

Pollen of this genus was identified fairly frequently in zones II and III of the series at Hawks Tor in the lowest of the Parsons Park samples, and in all samples of the lower muds from Stannon Marsh. Iversen (1946, 1947*a*) has recorded the pollen also from the late-Glacial in Denmark, and we may note that identification of a fruit of *Thalictrum alpinum* L. is recorded in § 4*a*, p. 430.

Typha

The characteristic pollen tetrads of *T. latifolia* occurred sparsely in zones II and III of the Hawks Tor series and at the base of the Stannon Marsh lower muds. They are not recorded by Jessen as occurring before zone IV in Ireland, but Iversen (1946) records them from zones II, III and IV at Bromme. *Typha* fruits were identified from the zone II muds at Hawks Tor, site 42B.

Valeriana officinalis agg.

The very readily recognizable large grains of *V. officinalis* were found rather freely in zones II, III and IV of the Hawks Tor series, as well as in the lower muds at Stannon Marsh and one of the two bottom samples from Parsons Park. Iversen (1946) has recorded this pollen type from zone II at Bromme, and we have encountered it elsewhere in English late-Glacial deposits, where, however, its fruits have not yet been found, although those of *V. dioica* do occur.

Notable absentees

Before concluding our comments on the Cornish late-Glacial pollen identifications it is desirable to mention two or three absentees from the lists.

Pollen of *Hippophae* (sea-buckthorn) is so consistently abundant in late-Glacial deposits on the mainland of Europe that its almost total absence from corresponding deposits in the British Isles is very striking.

Juniperus has been recognized in several recent investigations of late-Glacial vegetation, and Iversen (1946) has pointed out that its pollen may be recognized. Although tentative identification of *Juniperus* fruit has been made from the Hawks Tor material, we have so far been unable to identify pollen. Similarly, we have been unable to identify pollen of *Populus* although its pollen is also stated to be recognizable (Iversen 1946), and remains of *Populus* have been found at other late-Glacial sites in Britain (Pennington 1947; Jessen 1949).

Unidentified pollen types

Pollen grains which have been listed as 'cf. *Ligustrum*' occur in zones II, IV and VI of the Hawks Tor series. They correspond very closely indeed with grains of *Ligustrum vulgare* (see Erdtman 1943, p. 114), but the restricted distribution northwards of that species makes one loth to accept the identification until other possible alternatives have been examined.

From one of the samples of the lower muds at Stannon Marsh a very distinctive small tricolpate grain was identified which is tentatively listed as 'cf. *Ononis*'.

(*f*) *Post-Glacial pollen*

Lonicera periclymenum L.

Pollen of *Lonicera* is unmistakably present in the sample from the base of the lower peat in the Hawks Tor 42A series, and in zones IV, V and VI in the Hawks Tor 36 series. *Lonicera* pollen was quite abundant in the samples from zone VI. It corresponds with *L. periclymenum* which is generally taken to be the one species native to Britain. The main central European character of the distribution of this species lends special interest to its identification from such early deposits. Faegri (1943) has recorded the pollen from the sub-Boreal and sub-Atlantic periods in western Norway.

Hedera helix L.

Sparse pollen of *H. helix* has been identified from the end of zone V and zones VI and VII of the Hawks Tor 36 series. Jessen has recorded its pollen from zone VI onwards in Ireland. In his comprehensive study of *Viscum*, *Hedera* and *Ilex* as climatic indicators (Iversen 1944*a*), it is demonstrated that the high frequencies of ivy pollen occur in the second half of the Boreal period and the Atlantic, although a few are found earlier.

Ilex aquifolium

A single pollen grain of holly was identified at 175 cm. (zone VII) in the Dozemare Pool series. The pollen has been recorded from zone VI onwards in Ireland (Jessen 1949) and two *Ilex* grains were found (though hitherto unrecorded) in the deep submerged peat at Swansea (lowest sample of bore no. 35) which was referred to zone VI*a* (Godwin 1940*a*).

6. Discussion and conclusions

The value and interest of the foregoing observations upon Cornish deposits lie in two directions, first in establishing the nature of late-Glacial conditions in the south-west of England, and secondly in giving positive data of the former distribution of the British flora for a period and place of great importance in the theory of the history of that flora.

The presence of deposits with a general late-Glacial character is confirmed by a series of features:

(i) *Evidence at the Hawks Tor pit of solifluction and cryoturbatic phenomena in the upper and lower gravels and sands* (see § 1*b*; 2*b*, i, ii, iii). These effects are indicative of freezing and thawing upon mobile material in peri-Glacial conditions, and have been elsewhere recognized in their various forms as characteristic of the late-Glacial period.

(ii) *The occurrence of several plant species at present of more restricted northern range* (see § 4*a*). It is possible to regard the presence of such species as *Salix herbacea*, *Betula nana*, *Thalictrum alpinum*, *Subularia aquatica*, *Polytrichum alpinum*, etc., as directly indicating colder climatic conditions than those of to-day. Even if it were conceded that they later disappeared from this region because of the spread of closed forests, the implication of climatic change remains. It is to be noted that these species chiefly occur in the organic layers next either to the surface of the basal gravel, or to the under-surface of the gravelly-soil layer, whilst the *Subularia* and *Polytrichum alpinum* at site 42B usually occur in the basal gravel itself.

The lack of these northern species from the middle portion of the organic layers between the upper and lower gravels (zone II) need not, however, necessarily mean that they were not growing in the neighbourhood at this time.

(iii) *Position at the base of a long sequence of pollen zones*. The peats which overlie the deeper basin deposits very clearly show a succession of pollen zones extending backwards from the time of the post-Glacial climatic optimum, that is, from the period of the alder-mixed-oak forest to that of birch-pine. The sequence embraces zones VII, VI and V of the English zonation, whilst at Hawks Tor probably zone IV is also present. This makes it certain that the underlying deposits are at latest of early post-Glacial age, and probable that they are late-Glacial.

(iv) *Pollen evidence for vegetation of late-Glacial type*. In the organic deposits between and within the gravel layers at Hawks Tor pollen-analysis has shown the presence of a herbaceous land vegetation similar to that common in late-Glacial deposits elsewhere in western Europe. It includes the genera *Armeria*, *Artemisia*, *Helianthemum*, *Thalictrum*, *Scabiosa*, *Valeriana*, *Plantago*, *Botrychium*, etc., and is rich in genera and species intolerant of closed forest conditions.

A much closer correlation with the late-Glacial of western Europe would be assured if we were able to recognize in the Cornish deposits evidence of the Allerød climatic oscillation. This must rest upon a demonstration that a phase of milder climate interrupts the general severity of the late-Glacial period. Evidence for this is found in three further sets of data:

(v) *Evidence of a period of formation of organic muds and peats between the layers of solifluction material*. This is apparent at Hawks Tor, and possible at Stannon Marsh. The formation of these organic layers itself points to the presence of continuous vegetation cover, and hence milder conditions, for a substantial time between the formation of the lower and upper gravels.

(vi) *Diatom evidence for temperate climatic conditions in the lower muds*. In the appendix to this paper Mr R. Ross discusses the conclusions which can be drawn from examination of the diatomite layer at the bottom of the channel at site A, 1936. He concludes: 'we may deduce with some certitude that the temperature at the time when this deposit was being laid down did not differ appreciably from that of England at the present day.' This conclusion is based, of course, upon the geographical range of the extensive list of diatom species; more precise autecological knowledge of the diatoms as climatic indicators is lacking, but it is quite apparent that 'arctic-alpine' species are very few, and even 'temperate-alpine' species much less frequent than 'temperate'.

(vii) *Evidence of warmth-indicating species of mosses and phanerogams from the lower muds and peats*. From the upper part of the Hawks Tor muds at site 42B (i.e. the middle of the organic layers) has come the moss *Antitrichia curtipendula*, a species which barely reaches the Arctic Circle, and this, taken with *Climacium dendroides* from the same sample carries an implication of somewhat milder conditions than those suggested for the gravel layers. A small group of seed identifications, including *Lycopus europaeus* and possibly *Veronica anagallis-aquatica* (§ 4*a*), are also of species of relatively southern range, which occurred wholly, or almost wholly, in the middle of the organic layers beneath the gravelly-soil. It is apparent that this evidence from bryophytes and cormophytes is only a weak indication of climatic amelioration, and the pollen-analyses afford no clear index to this either.

No one who had seen the great isolated granitic blocks resting in the coarse unsorted gravels above and below the lower peats and muds, and who had seen the folding and incorporation of these muds and peats into the overlying gravel, would doubt that the organic layers must have been laid down under much less cold conditions than were the gravels both below and above. A clear idea of the character of those temperature conditions is afforded by the plant remains associated with the transition layers on the upper and lower surfaces of the lower peat.

Taking together the evidence here summarized it seems difficult to resist the conclusion that we are indeed concerned with an effect of the late-Glacial Allerød oscillation, and that it is reasonable to correlate the muds and peats with zone II, and the overlying gravelly-soil with zone III of the sequence in use for north-west Europe. The only alternative to accepting the Cornish deposits as equivalent to the Allerød stage of the late-Glacial would seem to lie in the supposition that the lower muds and peats are of greater age than late-Glacial, i.e. are inter-Glacial or interstadial. They are, however, of too slight a character for this, represent too unvaried a vegetation, and are sealed in by too trivial a deposit.

On the other hand, it must be admitted that if these deposits represent the Allerød oscillation, it is in a form somewhat different from that usually described. This is particularly so in the apparent absence of tree growth in zone II, a feature we might infer from the absence of fruit, cone scales, or wood (apart from *Salix*), as also from the low tree/non-tree pollen ratio. This treelessness would be more remarkable because of the southerly latitude, and the prompt appearance of warmth-demanding trees above the gravel layers in what is presumably zone IV. If this treelessness is a reality, it might be attributed to altitude, thin soil, or exposure, but it is equally possible that the absence of evidence for tree growth is a fortuitous effect of conditions of incorporation at the site.

If we agree that the Allerød oscillation is indeed represented, we are thrown back upon the problem of the nature of the vegetation at the commencement of the post-Glacial period, a matter already considered somewhat in § 5*c*. Since in zone IV pollen of warmth-demanding trees is already present in appreciable amount, it might be thought that these trees were in fact growing either in Cornwall or not far away at this time, although apparently they were not in zone II. The majority of Allerød sites have been described from basins formed as kettle-holes in the terminal moraines of the last glaciation, and we must expect that at sites well outside the glaciation limits both stratigraphic and vegetational phenomena will differ appreciably. The true picture can only emerge when more sites have been examined in a peripheral region outside that where the Allerød occurs typically developed.

It has only recently been realized how profoundly our views upon the status of the British flora may be affected by knowledge of late-Glacial conditions and events in this country. In particular, problems of pre-Glacial survival, immigration, and rates of migration, in many instances take a different form when seen in relation to the established occurrences of the late-Glacial period. As this subject has been generally considered elsewhere (Godwin, 1949), we need not do more than refer to it. It must, however, be observed that in Cornwall as elsewhere it appears that in late-Glacial times many herbaceous plants addicted to open ground flourished, but that later they suffered restriction and extinction, in part perhaps directly through climatic change, but almost certainly to a large extent through extension of forest or peat mire. We may, for instance, note how the discovery of pollen of *Polemonium coeruleum*, so far from sites where it now grows naturally, must influence our views upon the history of this plant in Britain, and how the discoveries of arctic birch and willow confirm the former widespread distribution and subsequent restriction of these species.

We are not, unfortunately, in the position of being able to mention a fossil occurrence of any of the species now characteristically localized in south-west Britain, but there is no reason why trace of them should not be found. The results already obtained show how prolific these deposits can be, and doubtless many others of comparable age and character await fuller investigation.

Mr C. A. Ralegh Radford, F.S.A., was most helpful in the early stages of our investigations, in advising as to the most suitable sites. Mr C. Croft Andrews also gave valuable information and assisted with the field-work at Dozemare Pool.

We are indebted to the Council of Newnham College, Cambridge, for the award to two of us (E. M. M. and A. P. C.) of studentships through which it was possible to pursue this research in Cambridge. Our very grateful thanks are given to Mrs Hazel Whitmore and Miss Robin Andrew, who, as scientific assistants, were responsible for a good deal of the pollen counting, Miss Andrew especially for the identification and recording of pollen of late-Glacial herbaceous plants. We gratefully acknowledge also assistance and courtesy from the manager of the Hawks Tor China-Clay Works, the foreman of the china-clay pit at Parsons Park, and Dr Hooper of Falmouth Public Library.

Finally, we wish to express thanks to Mr Ross for the thorough analysis of the diatomite which forms the appendix to this paper.

APPENDIX

Report on diatom flora from Hawks Tor, Cornwall

By R. Ross

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A sample of the diatomite collected from the base of the lower muds and peats at the kaolin china-clay pit at Hawks Tor, Bodmin, was submitted to me by Dr Godwin. In it sixty-three species of diatoms were found, of which a number were represented by more than one variety, there being seventy-four different forms in all. A list of these is given below in which the relative abundance, the present geographical distribution and the ecological preferences of each diatom are indicated.

The names in this list are applied in the sense adopted by Hustedt (1930) in the latest comprehensive account of the diatoms of the fresh waters of western and central Europe. Some of the nomenclature adopted in that work is, however, not in accordance with the *International Rules*, and where this is the case the legitimate name has been used, or a new and legitimate combination made. Mills (1933–5) or Ross (1947) provide the synonymy necessary to relate these legitimate names to those used by Hustedt.

No objective value for the relative frequency of the various diatoms could be obtained as any procedure based on counting was made impossible by the number of broken valves present. A subjective estimate was therefore made for each species using the terms conventionally employed in plant-ecological field-work.

Most diatoms have a very wide geographical distribution, but it proved possible to group the forms found into four classes according to whether or not they are at present generally distributed in western and central Europe and whether they are as common there as farther north or south. The geographical divisions adopted are as follows:

Arctic-alpine: known at present only from northern Europe or from high altitudes in the mountains of central Europe.